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ABSTRACT

This study guide is part of a curriculum entitled Science and Engineering Technician (SET) Curriculum, a program of studies which integrates elements from the disciplines of chemistry, physics, mathematics, mechanical technology, and electronic technology. The purpose of this national curriculum development project was to provide a framework for training technicians in the use of electronic instruments and their applications. This guide is designed to be used as a supplement to a manufacturing processes text which deals with materials properties, heat treatment, and plastics. Training in materials and fabrication methods, and in those skills which are useful in a technical laboratory environment, are provided. The following topics are included in the text: (1) measurement; (2) electrical fabrication; (3) hand tools; (4) power hand tools; (5) power bench tools; and (6) metal fabrication. (Author/SK)

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Materials and Fabrication Methods 1

A study guide of the Science and Engineering Technician Curriculum

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2

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15. Abstract

This study guide is part of a curriculum entitled the Science and Engineering Technician Curriculum (SET), a program of studies which integrates elements from the disciplines of chemistry, physics, mathematics, mechanical technology, and electronic technology. The purpose of this national curriculum development project was to provide a framework for training technicians in the use of electronic instruments and their applications.

Materials and Fabrications Methods I is designed to be used as a supplement to a manufacturing processes text which deals with materials properties, heat treatment, and plastics. This guide provides training in materials and fabrication methods, and in those skills which are useful in a technical laboratory environment. The following topics are included in the text: (1) measurements, (2) electrical fabrication, (3) hand tools, (4) power hand tools, (5) power bench tools, and (6) metal fabrication.

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Science Curriculum
Engineering Technicians
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Laboratory Equipment
Machine Tools
Repair

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MATERIALS AND FABRICATION METHODS I

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Introduction

Materials and Fabrication Methods I is designed to acquaint students with materials and fabrication methods and skills which may be needed in a technical laboratory environment. Realizing many labs have limited types of equipment available or limitations on what work the technician can do, the course is expected to stress the use of hand tools, or portable power tools. Safety and alternate methods of doing fabrication are to be continually stressed.

Lathe, drill press and milling machine operations should be included where the industry needs being filled require knowledge or repair of accurately machined parts.

This manual should be used to supplement a clear, easy-to-read manufacturing processes text with sections on materials properties, heat treatment and plastics.

I. MEASUREMENTS

Common measurements for lab work are made for length, mass angles, and time. The two common units of measure are International System (SI) a metric system, and English.

I.1 LENGTH -

S.I. UNITS

1 METER (m) = 39.37 (in.)

1 (cm) = $\frac{1}{100}$ (m) = .01 METERS (m) = .3937 (in.)

1 (mm) = $\frac{1(m)}{1000}$ = .001 (m) = .03937 (in.)

Name	Symbol	Power of 10
pico-	pf	10^{-12}
nano-	n	10^{-9}
micro-	μ	10^{-6}
milli-	m	10^{-3}
centi-	c	10^{-2}
deci-	d	10^{-1}
deka-	dk	10^{1}
hecto-	h	10^{2}
kilo-	k	10^{3}
mega-	M	10^{6}

ENGLISH

1 (ft.) = 12 (in.) = .3048 (m)

1 (in.) = $\frac{1}{12}$ (ft) = .02540 (m)
= 2.540 (cm)

.001 (in.) = .00254 (cm)
= .0254 (mm)

1 YARD = 3 (ft.) = .9144 (m)

LABORATORY

The student should know how to convert units from English to metric and back to English. The prefixes indicating powers of 10 should be known.

I.1 STUDENT PROBLEMS

Convert each of the units using Table #1 of the Appendix.

A. 10 in. = _____ m = _____ mm = _____ cm

B. 6.3 cm = _____ in. = _____ ft. = _____ m

C. 25.56 mm = _____ in. = _____ cm = _____ m

D. 2.625 in. = _____ cm = _____ mm = _____ m

Specify each of the units.

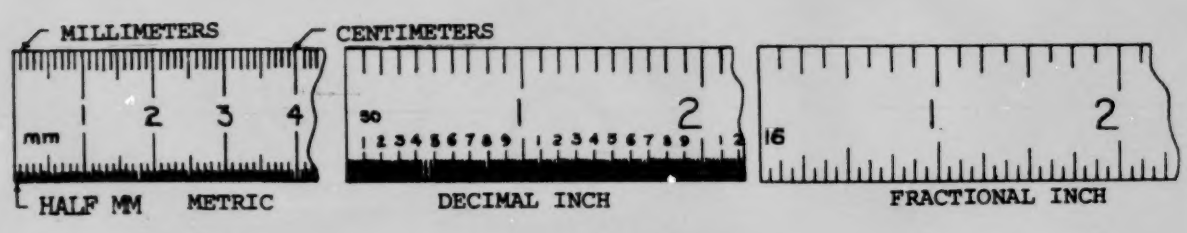
E. 2.56 meters = 256. _____ = 2560 _____

F. 5,943,000. = 5.943 _____ = 5943. _____

I.2 LENGTH MEASURING INSTRUMENTS

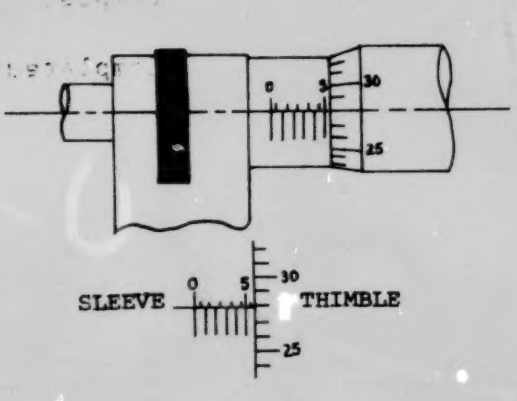
Linear measurements are made with:

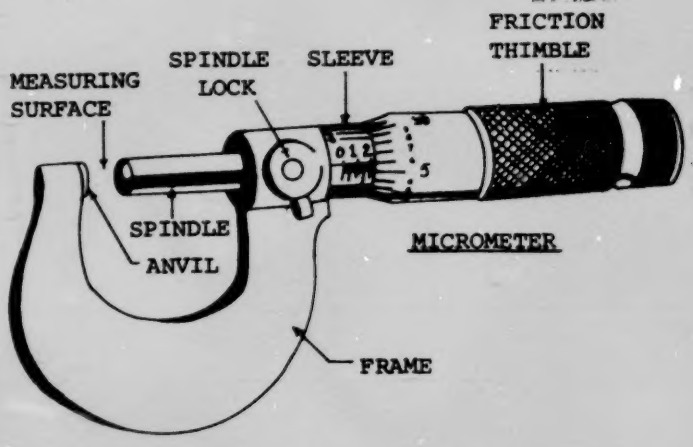
SCALES - for larger measurements



DIAL INDICATORS

Micrometers for precision measurement.

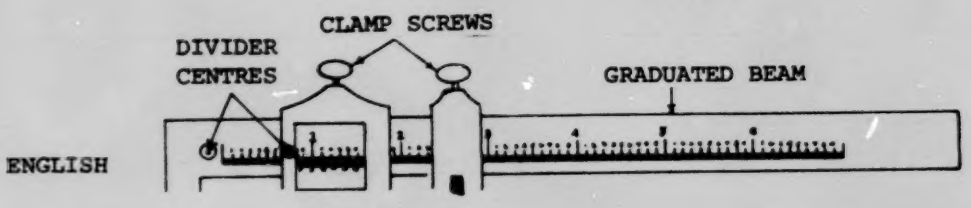




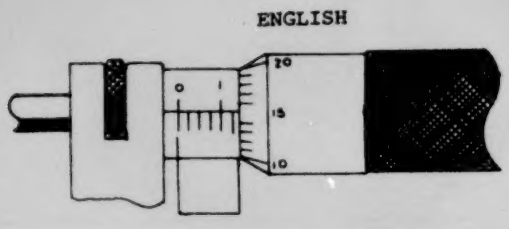
READING 5.78 mm

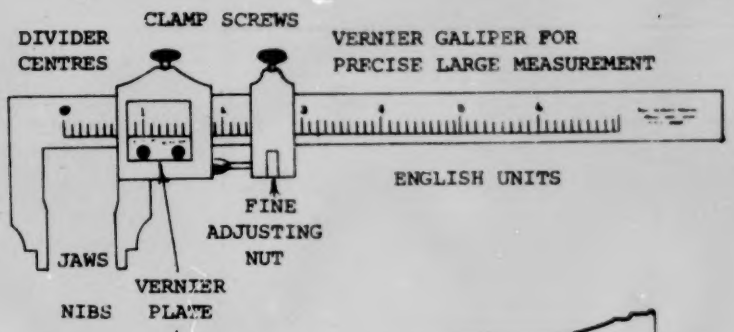
Metric micrometer reading of 5.78 mm

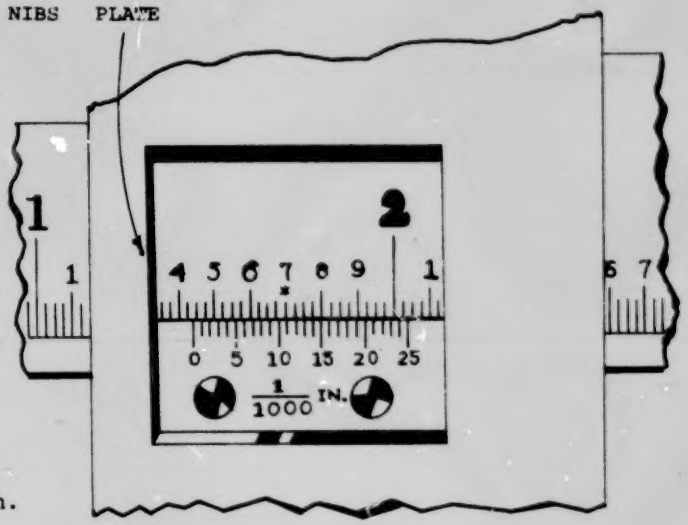
Vernier caliper for precise large measurements.



Micrometer Reading





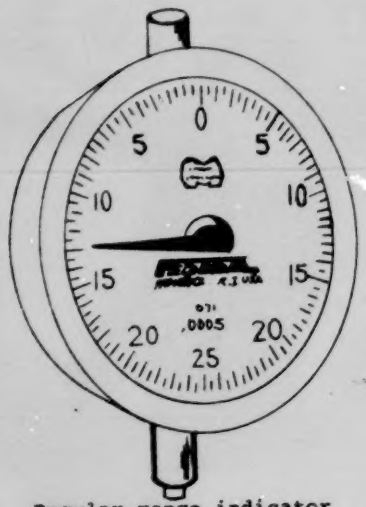


0.125 + 0.015 = 0.140 TOTAL INCHES

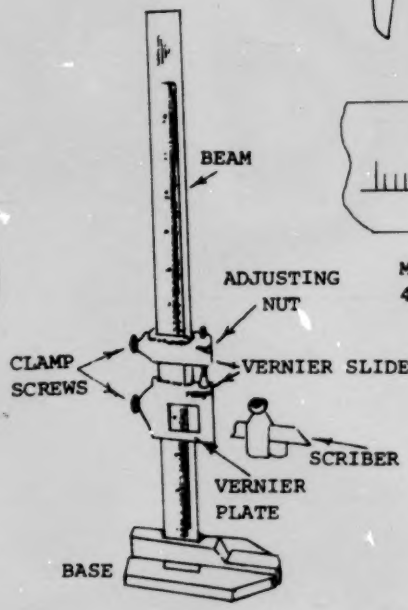
Vernier Reading

The large #1 on the bar		= 1.000
The small #4 past the #1	4 x .100 =	.400
One line is visible past the #4	1 x .025 =	.025
The 11th line on the vernier scale coincides with a line on the bar	11 x .001 =	.011
Total reading		= 1.436 in.

Dial indicators and height gauges are used for precise vertical measurement.



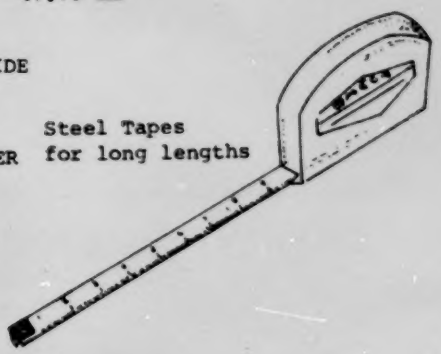
Regular range indicator



Metric Vernier Caliper

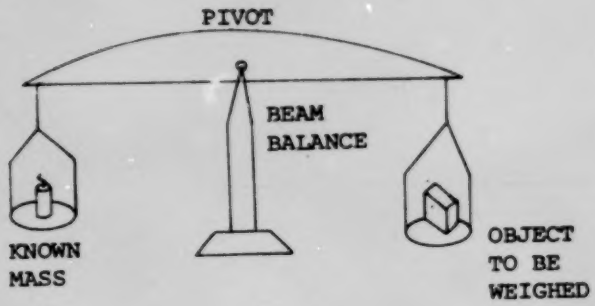
Metric Vernier Caliper Reading
47.75 mm

Steel Tapes for long lengths



I.3 MASS

Mass is a property of a substance. The mass of an object is measured by comparing with a know mass.



METRIC UNITS

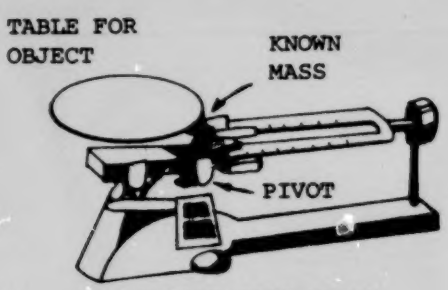
MASS IS IN KILOGRAMS (kg.)

1 kg = 1000 grams

ENGLISH ENGINEERING UNITS

MASS IS IN POUNDS (lb)

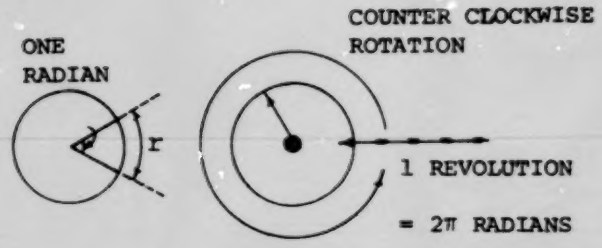
1 kg = 2.20462 lbs



TRIPLE BEAM SCALE

I.4 ANGLES

An angle is the measure of the difference in direction of one line or surface relative to another that intersects it. Angles are measured in degrees, radians or revolutions.



1 radian = 57.3 degrees

1 radian = $\frac{1}{2\pi}$ revolutions

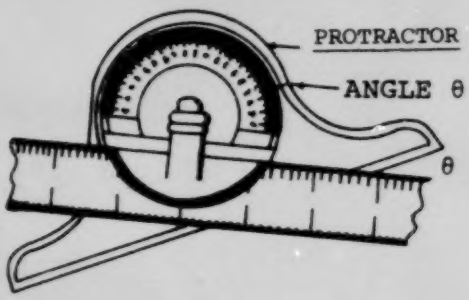
1 angle degree = 60 minutes of angle

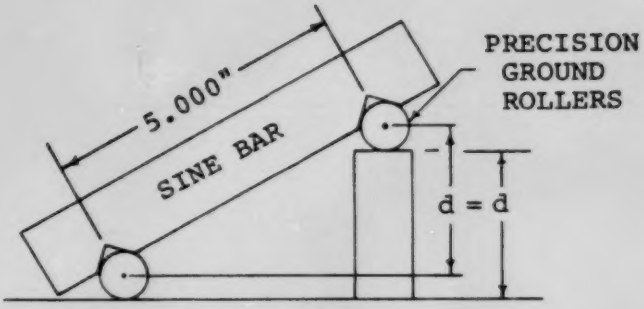
1 minute of angle = 60 seconds of angle

RADIAN - rad

The radian is the plane angle formed by two radii cutting an arc equal in length to the radius.

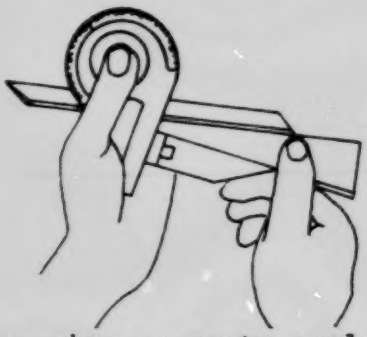
Angles can be measured directly with a protractor or indirectly by making length measurements using a sine bar.



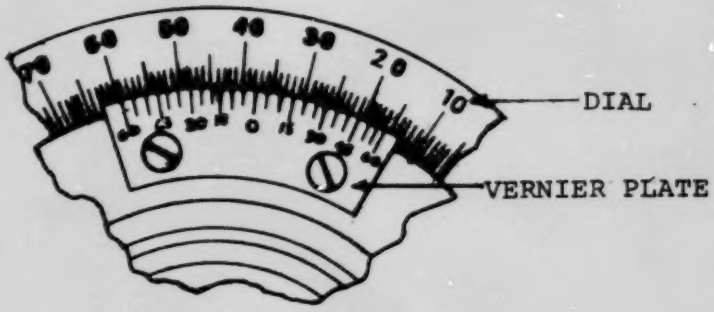


$$\sin\theta = \frac{d}{5.000"}$$

$$\theta = \text{arc sin}\ \frac{d}{5.000"}$$



Measuring an acute angle



Vernier Protractor Scale

Number of whole degrees is indicated by degrees between the zero on the dial and the zero on the vernier plate. Number of minutes is indicated by the line on the vernier plate which matches a line on the dial

Total reading $37^{\circ}\ 40'$

SPEEDS AND FEED RATE

Speed is a distance moved in a given time interval. Speed is also called a feed rate.

$$\text{Ex: speed} = \frac{10 \text{ feet}}{2 \text{ minutes}} = 5 \text{ ft/min}$$

$$\text{or } \frac{3.05 \text{ m}}{120 \text{ seconds}} = .02542 \text{ m/s}$$

Angular speed is angular movement in a given time interval.

$$\textbf{ANGULAR SPEED} = \frac{\text{angle moved}}{\text{time interval}} \quad \text{For example: } \frac{100 \text{ revolutions}}{1 \text{ minute}} = 100 \text{ RPM}$$

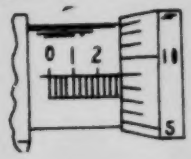
LABORATORY

The student should know and be capable of making length measurements and angle measurements using metric and English; micrometers, vernier calipers and height gauges, scales, protractors, and vernier protractors.

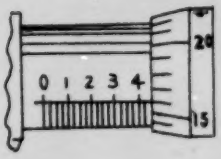
STUDENT PROBLEMS

Read the micrometer, vernier and protractor scales shown.

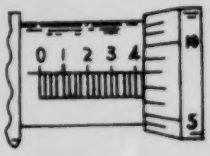
MICROMETER



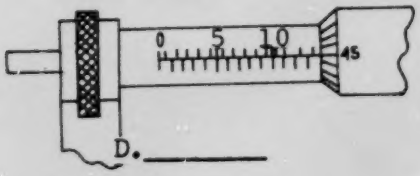
A. _____



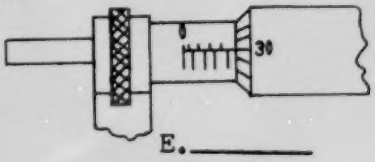
B. _____



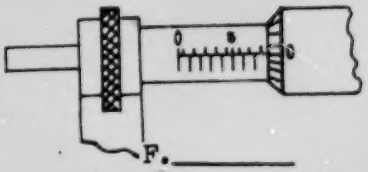
C. _____



D. _____

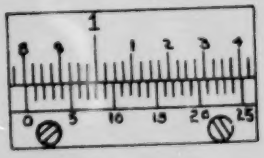


E. _____



F. _____

G. _____



H. _____

I. _____

VERNIER

J. _____

VERNIER PROTRACTOR

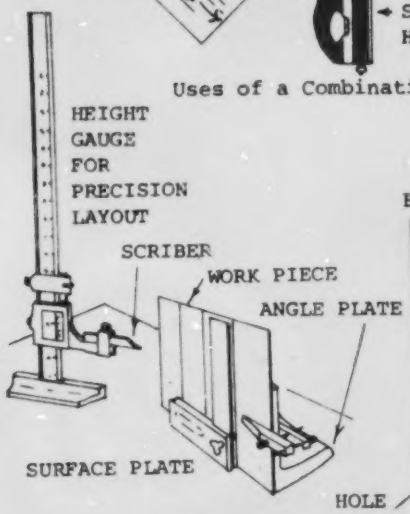
K. _____

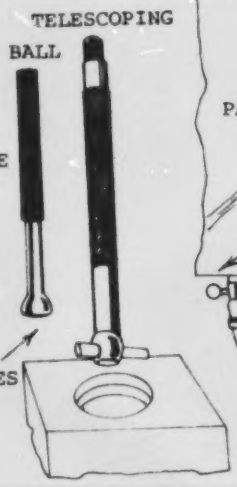
L. _____

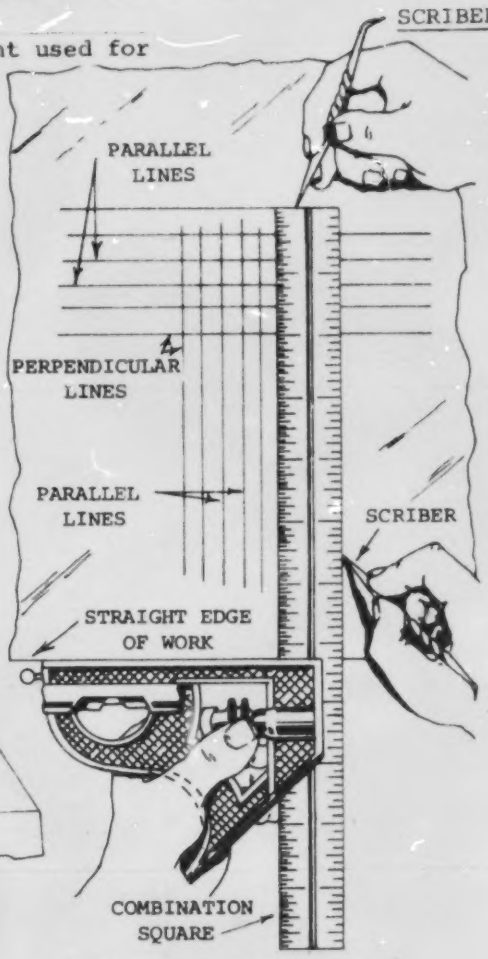
1.5 LAYOUT

Layout is marking cuts and hole locations or bends before making or fabricating parts.
Following are examples of equipment used for layout work.

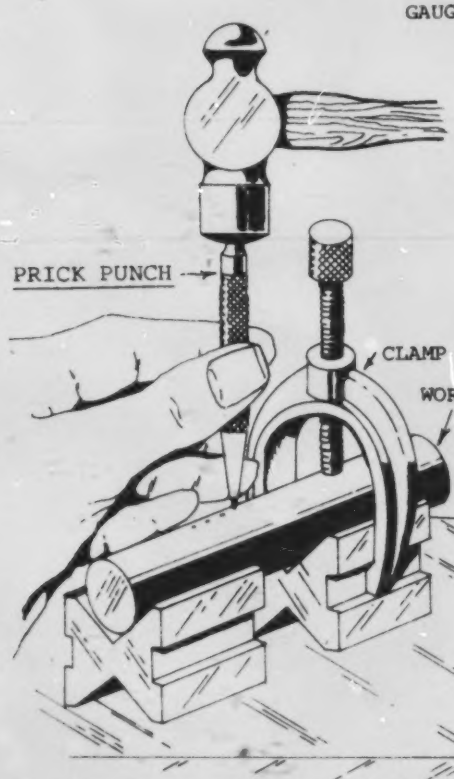
Uses of a Combination Square

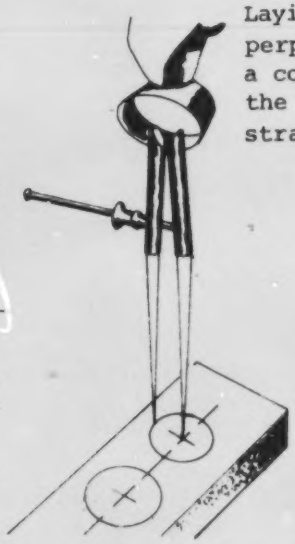




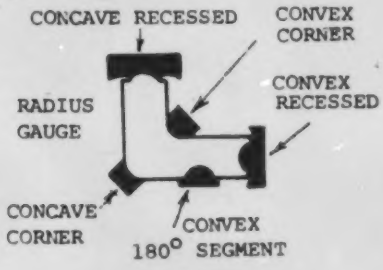


Laying out parallel and perpendicular lines with a combination square when the work has only one straight edge





Uses of V-Blocks in Layout Work



RADIUS GAUGE

Circles are drawn on metal with DIVIDERS.

LABORATORY OBJECTIVES AND SKILLS

The student should be able to do a layout having a pattern of parallel and perpendicular lines relative to two reference axes and to indicate circles on the layout.

STUDENT PROBLEMS

Indicate the layout equipment necessary to produce each of the following:

A. Circle of 2.0 inch diameter. _____

B. Two parallel lines parallel to the base of a block. _____

C. A straight line at an angle of $34^{\circ}52'$ to the edge of a metal sheet. _____

D. Scribe a rounded corner with a 1/4 inch diameter radius tangent to two perpendicular sides. _____

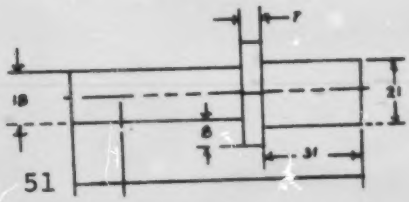
E. Produce an accurate punch mark at the intersection of two scribed lines.

I.6 END OF CHAPTER REVIEW PROBLEMS

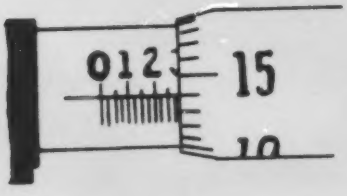
1. A drawing gives dimensions in mm. Convert the length to inches.

   1 mm = .03937 in.

   51 mm = 51 mm x .03937 in/mm = 2.0079 in.

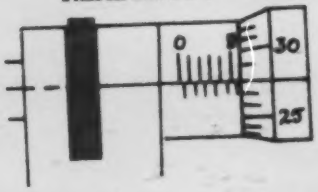
Fig. Prob. 1

ALL DIMENSIONS IN mm

2. Determine the micrometer reading shown.

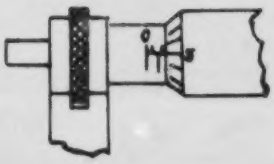


0. 289 in. READING

MARK THE READINGS.



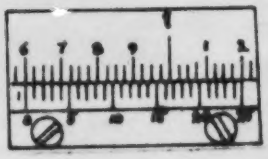
_____ mm



The reading is composed of:
2 large graduations or 2 x 0.100 in. = 0.200 in.
3 small graduations or 3 x 0.025 in. = 0.075 in.
and 14 graduations on the
thimble or 14 x 0.001 in. = 0.014 in.
Total reading = 0.289 in.

_____ mm

STUDENT EXERCISES



Convert the dimensions from the figure of problem 1 above to English units.

_____ in

18 mm = _____ in. 8 mm = _____ in.

21 mm = _____ in. 7 mm = _____ in.

31 mm = _____ in.

Section I.4 Problems

A. (.284) B. (.441) C. (.408) D. (14.45) E. (4.80)

F. (8.00) G. (7.028) H. (.8005) I. (1.795) J. (53.65)

K. (55° 15') L. (12° 15')

Section I.5 Problems

A. dividers scale

B. surface plate height gauge angle plate scriber

C. vernier protractor scriber

D. 1/4" radius gauge scriber

END OF CHAPTER ANSWERS

.7087 in. .3150 in.
.8268 in. .2756 in.
1.2205 in.

A. ANSWERS (.254) (254.) (25.4)

B. ANSWERS (2.480) (.2067) (.0630)

C. ANSWERS (6.66) (66.675) (.066675)

D. ANSWERS (1.0063) (2.556) (.02556)

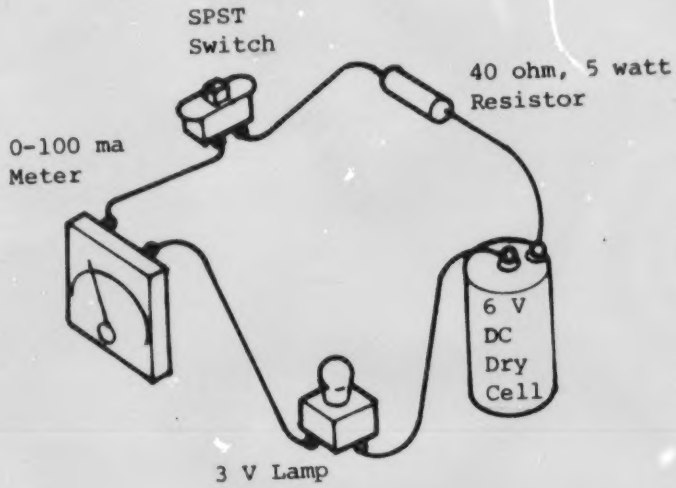
E. ANSWERS (cm) (mm)

F. ANSWERS (mm) (km)

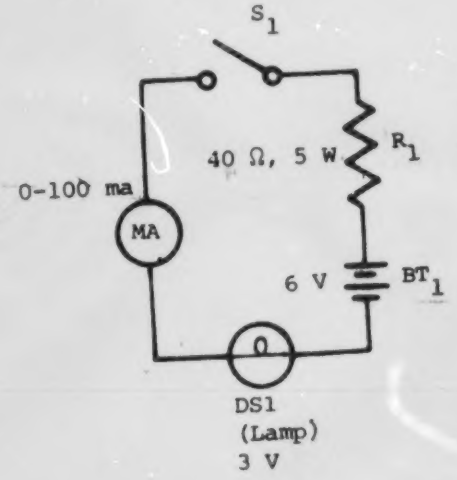
II. ELECTRICAL FABRICATION

II.1 Introduction

To assemble, fabricate and/or better understand electrical or electronic equipment (hardware), a schematic drawing is necessary. Sometimes referred to as an elementary circuit drawing, the schematic diagram is a condensation of an electrical circuit. Components are represented by generally accepted symbols arranged in an orderly manner with the shortest possible routes used to interconnect these symbols.



Wiring Diagram



Schematic Diagram

A wiring diagram differs from a schematic diagram in that it shows point-to-point interconnections between components shown pictorally or as pictoral outlines in their actual locations.

To understand either the schematic diagram or wiring diagram it is important to recognize and understand the components involved.

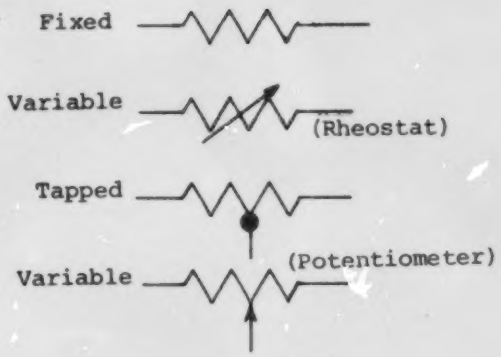
II.2 COMPONENT IDENTIFICATION & SCHEMATIC SYMBOLS

A. Resistors

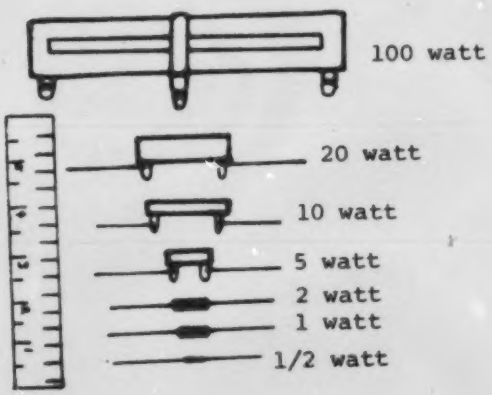
The resistor symbol is perhaps the most frequently encountered, passive, electronic component.

The resistance is measured in ohms and serves to impede current flow (the movement of electrons).

The resistor is rated in watts (power) which is a way of determining how much current it can handle without burning or shorting out.

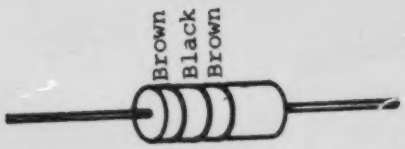


Resistor Symbols & Types



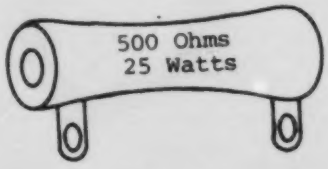
The resistors shown in the adjacent figure may all have the same value of resistance (measured in ohms) but differ in their current handling capacity (power).

Resistors control current flow in electrical circuits.

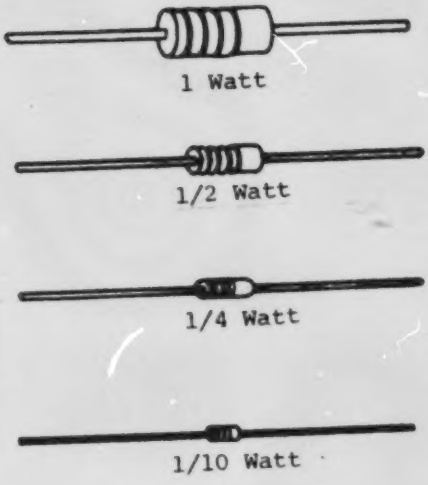


2 Watt
100 Ω

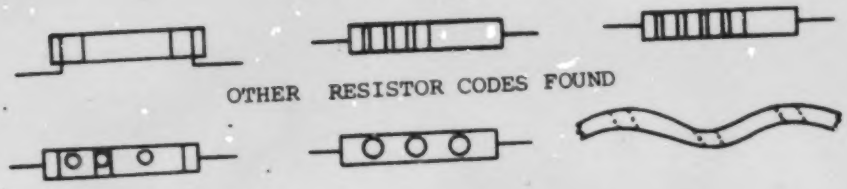
Resistors whose power ratings are below 5 watts are usually identified by color bands printed on the resistor. Above 5 watts, the value of a resistor is usually printed in numbers and letters.



Power Resistor



Color-Coded Resistors

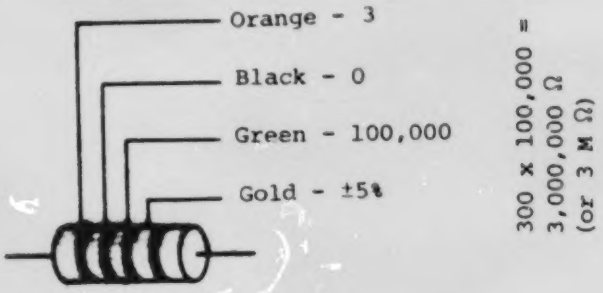


OTHER RESISTOR CODES FOUND

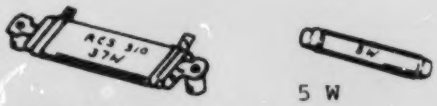
Color	1st Digit A	2nd Digit B	Multiplier C	Tolerance D	Failure Rate* E
			1	-	-
Black	0	0	10	± 1%	1.0
Brown	1	1	100	± 2%	0.1
Red	2	2	1,000	± 3%	0.01
Orange	3	3	10,000	± 4%	0.001
Yellow	4	4	100,000	-	-
Green	5	5	1,000,000	-	-
Blue	6	6	10,000,000	-	-
Violet	7	7	100,000,000	-	-
Gray	8	8	-	-	Solderable*
White	9	9	0.1	± 5%	-
Gold	-	-	0.01	±10%	-
Silver	-	-	-	±20%	-
No Color	-	-			

*Band E, when used on composition resistors, indicates percent failure per 1,000 hours. On film resistors, a white band E indicates soldering terminal.

Example of how to use color code.



10 W



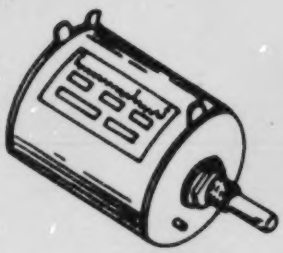
5 W

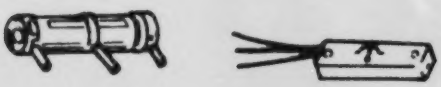
50 W

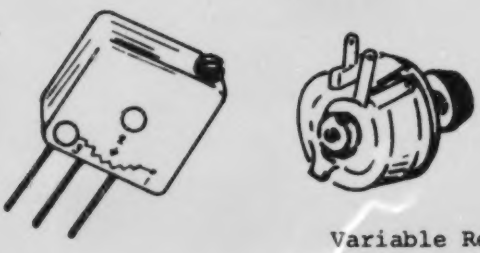
Power Resistors

Power Resistors

Power resistors, shown on the right, are so called because they are designed to dissipate a large amount of power in the form of heat. Over a period of time their markings may burn off.







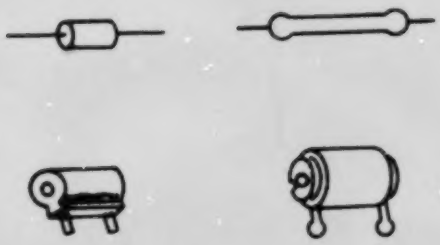
Variable Resistors

Variable Resistors

Variable resistors make it possible to vary the current or voltage in a circuit by varying the resistance. The volume control on your stereo is an example of a variable resistor.

Precision Resistors

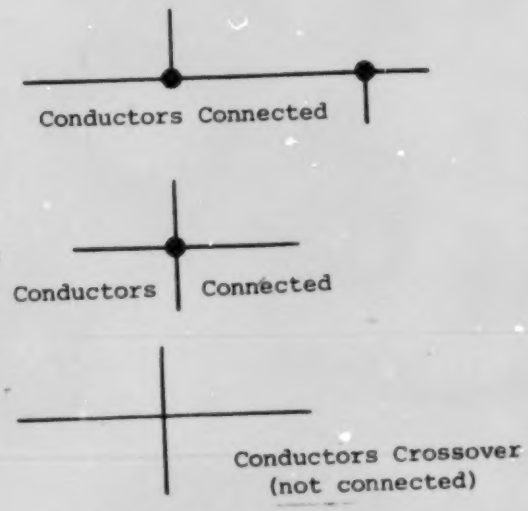
Many electronic circuits require very precise and exact resistance. These resistors may take on odd shapes and sizes to meet the tolerances and specifications required.



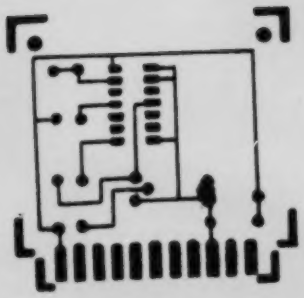
Precision Resistors

B. CONDUCTORS

Conductors interconnect electronic components to form a path for current to flow. Conductors may be wires or narrow "ribbons" of metal, usually copper. On schematic diagrams they are shown as simple lines. Connections are dotted intersections.



Conductor Schematic Symbols
(Dot System)



Printed Circuit

Conductors on printed circuit boards may be embossed with a metallic "paint" or etched from a completely covered, copper-clad board.

Consideration must be given to the current carrying capacity of various sizes of wires that may be used to interconnect electronic equipment. Table I offers data on the current handling capacity of wiring of various sizes.

TABLE I

Current Carrying Capacity of Conductors

Cable Size AWG		Continuous Duty Current - Amperes	
Aluminum	Copper	Single Wire In Free Air	Amperes Rating of Wires in a Single Conduit or Bundle
	22	--	5
	20	11	7.5
	18	16	10
	16	22	13
	14	32	17
	12	41	23
	10	55	33
	8	73	46
	6	101	60
	4	135	80
	2	181	100
	1	211	125
	0	245	150
	00	283	175
	000	328	200
	0000	380	225
8		60	36
6		83	50
4		108	66
2		152	90
1		174	105
0		202	123
00		235	145
000		266	162
0000		303	190

Wires in Bundles: Table I current ratings for wires in bundles are based upon 15 or more wires carrying no more than 20 percent of the total current carrying capacity of the bundle. In smaller bundles, the allowable percentage of total current may be increased as the bundle approaches the single-cable condition. For 20 AWG wire, example: 15 wires x 11 amps/wire x .20 = 33 amps capacity of bundle.

Various colored wires may be used to serve different functions. Table II is a listing of the Military Standard (122) of colors for chassis wiring.

AWG (American Wire Gauge) specified in circular mics on sizes above 0000 250 AWG = 250 000 circular mics of cross section area. Below 0000 the AWG number is just a specific size.

Table II

Color code for chassis wiring

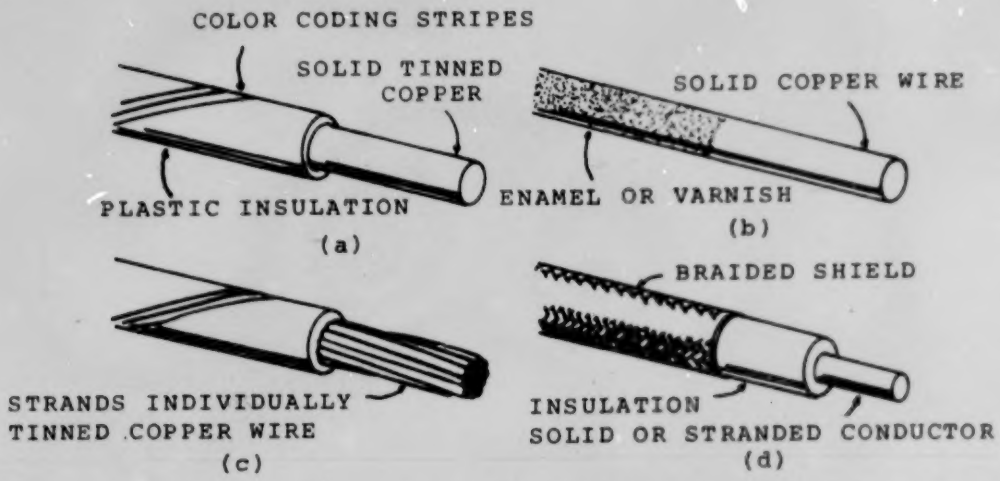
color	abbrev.	numerical code	circuit
Black	BK	0	Grounds, grounded elements and returns
Brown	BR	L	Heaters of filaments off ground
Red	R	2	Power supply B-plus
Orange	O	3	Screen grids
Yellow	Y	4	Cathodes, emitters
Green	GN	5	Control grids, base
Blue	BL	6	Plates (anodes), collectors
Violet (or Purple)	V PR	7	Power supply, minus
Gray	GY	8	AC power lines
White	W	9	Miscellaneous, returns above or below ground, AVC, etc.

Source: Mil Std 122.

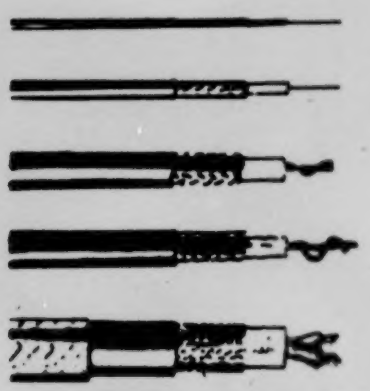
Wire Types

Conductors are of two basic types: single-strand (solid), and multistrand wire. Most wire used in electronics is made of copper covered with some form of insulating material to prevent electrical connections with other wire and metal parts it may touch.

Multistrand wire is more flexible than solid wire, and for this reason it is preferred for most wiring. Because of its flexibility, multistrand wire is also less subject to fatigue failure produced by vibration. Both solid and multiple stranded wires are often pretinned for ease in soldering.



Some types of wire used in electronics. (a) Solid hookup wire. (b) Magnet wire. (c) Stranded hookup wire. (d) Shielded wire.



Some typical coaxial cable sizes.

Laboratory Skill - To Use the VOM

The volt-ohm-meter shown at the right is a valuable tool for measuring continuity (does the circuit have a complete path for current to flow?), resistance, voltage, and current.

A voltohmmeter (VOM). or multimeter

1. It is expected that the student be able to use the VOM (voltohmmeter) or multimeter. In particular, he/she should be able to describe the function of the range-selector switch, and the use of the zero adjust knob.

2. The student should know where the range-selector switch should be set when the meter is not in use and be able to explain why the meter pointer deflected to infinity and then to zero on the meter scale when the test leads were alternately opened (separated) and shorted together.

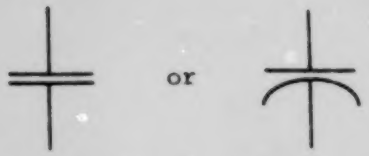
C. CAPACITORS

A capacitor is a device for storing electric charge. In its simplest form it is a pair of conducting surfaces separated by a dielectric (insulating) material.

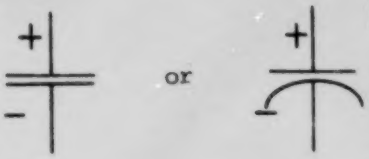
The capacitor symbols at the right reflect the fact that they are constructed of two metal plates (usually of a metal foil) separated by a small space.

The capacitance is measured in fractions of farads, microfarads or picofarads.* Additionally, capacitors are rated according to the voltage that can be placed across their "plates" before breaking down or "arcing".

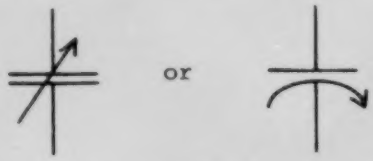
General purpose capacitors represent the majority of capacitors found in electronics. None are over 1 1/2 inches (4 cm) long. Identifying marks are not as standardized as the color code on resistors.



Basic Capacitor

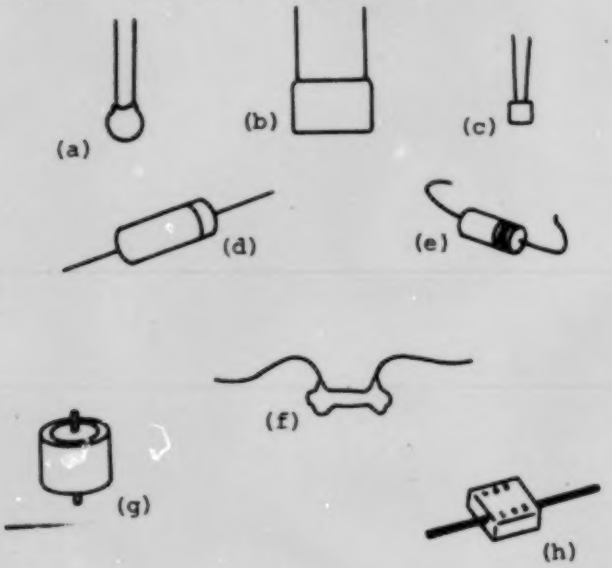


Electrolytic Capacitors



Variable Capacitors

Capacitor Schematic Symbols



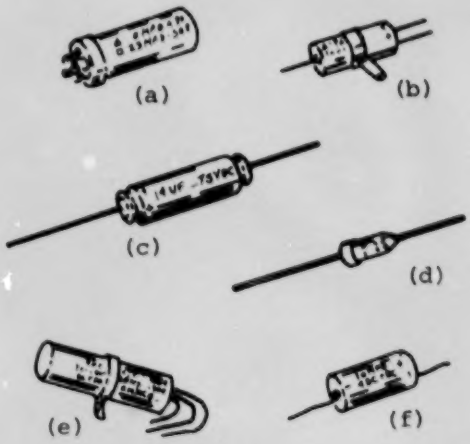
An assortment of general-purpose capacitors. (a) Ceramic disk capacitor. (b) Ceramic plate capacitor. (c) Microminiature ceramic capacitor. (d) Molded tubular capacitor. (e) Molded tubular capacitor. (f) Tubular ceramic capacitor. (g) High-voltage ceramic capacitor. (h) Molded mica capacitor.

*1 farad = 1 coulomb of charge 1 volt potential difference between the plates. 1 μF = 10^{-6} F; 1 pF = 10^{-12} F, also 1 μμF.

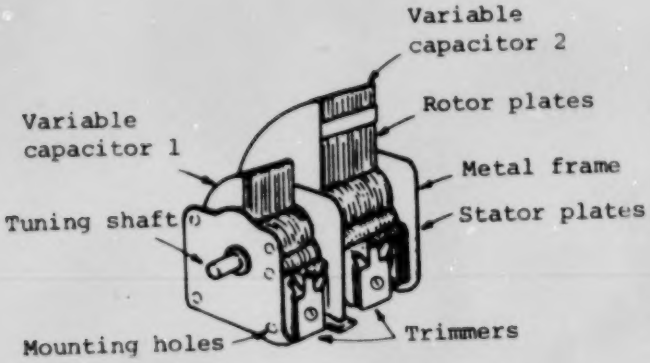
Capacitors have the ability to maintain (store) an electric charge (for a limited time). They serve also to block a DC current flow since there is no conductor between the plates. Alternating current may flow back and forth between capacitors.

Electrolytic capacitors use a chemical dielectric in the space between the plates.

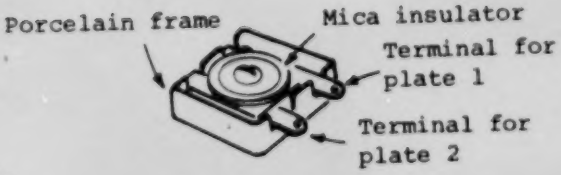
CAUTION: Electric current must flow only in one direction. When installing electrolytic capacitors be sure to consider the "polarity". Failure to do so may destroy surrounding equipment.



Electrolytic capacitors. (a) Twist-prong-can electrolytic capacitor. (b) Insulated-can dual electrolytic capacitor. (c) Foil-type tantalum electrolytic capacitor. (d) Slug-type tantalum electrolytic capacitor. (e) Wax-filled cardboard electrolytic capacitor. (f) Insulated metal tubular electrolytic capacitor.



(a)



(b)

Variable capacitors. (a) Two-gang variable capacitor. (b) Trimmer or padder capacitor.

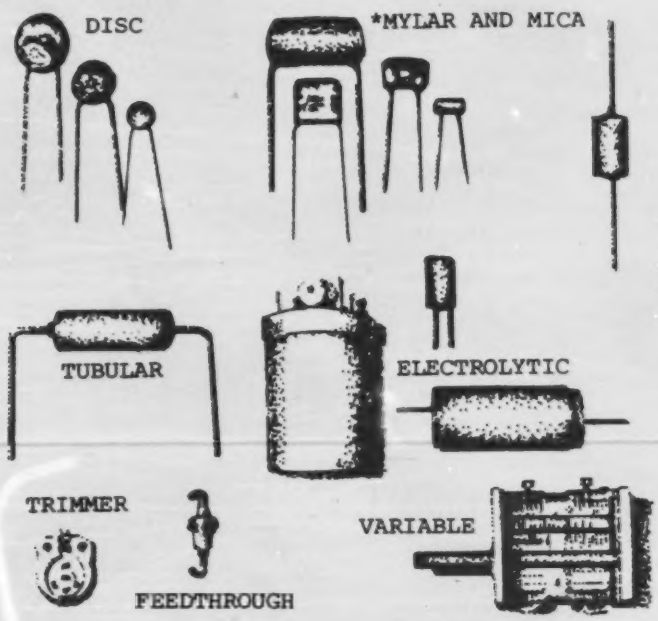
Variable capacitors are used in circuits which require the adjustment of capacitance. The two-gang variable capacitors 1 and 2 are mechanically "linked" through the shaft. Such a capacitor is found in radios and used to "tune" in stations.

(a) (b)

Hermetically sealed capacitors shown at the left use an oil or chemical electrolyte. They are also sealed to keep out moisture. They are used in high voltage power supply circuits.

Hermetically sealed oil or paper capacitors. (a) Hermetically sealed high-voltage rectangular capacitor. (b) Hermetically sealed bathtub capacitor.

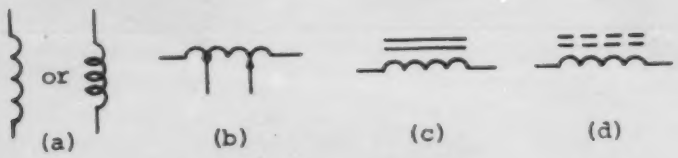
Many different types of capacitors are used in electronic circuits. Several of these capacitors are shown below.



*Mylar is a plastic dielectric material.

D. INDUCTORS

There is a wide variety of <u>inductors</u> used in electronic equipment. They may be identified or classed according to their use. They are used in both AC and DC circuits in different ways.



Inductor schematic symbols. (a) General symbols. (b) With fixed and variable taps. (c) With magnetic core. (d) With ceramic-type core.

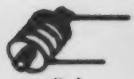
The schematic symbols (c) and (d) (with lines above the coil symbol) indicate the type of core in the inductor. At low frequencies, magnetic cores are used to increase the induced field. Ceramic cores are composed of magnetic materials called <u>ferrites</u>.

Inductance is measured in units called <u>henrys</u> (H)*. When specifying an inductor, a current rating is usually necessary along with the value of inductance. The <u>impedance</u> and/or <u>resistance</u> of an inductor may also be a required specification.

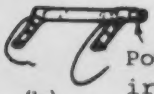
*1 henry (H) = 1 volt-second/ampere (1 $\frac{V\text{-}s}{A}$) and depends on the dimensions and material of the conductor (usually a coil).

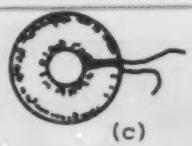
Samples of Inductors

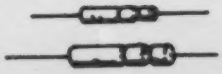
(a)


(b)

(a)

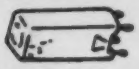

Powdered iron core
(b)


(c)


(d)

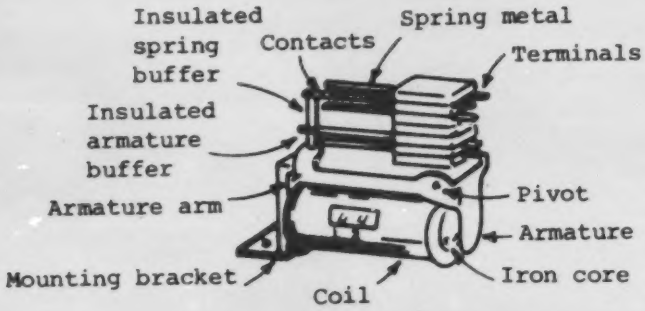
An assortment of chokes. (a) Low-frequency choke. (b) Pi-wound r-f choke. (c) Toroidal choke. (d) Tubular insulated chokes.

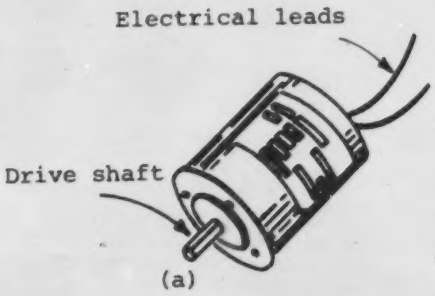
Transformer inside of can

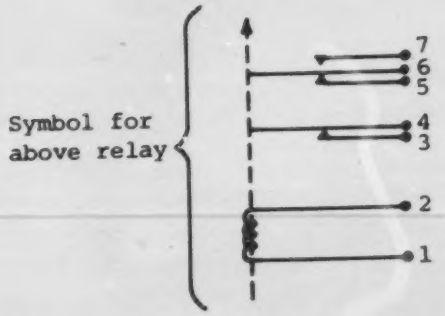

(c)

Technically a transformer
(d)

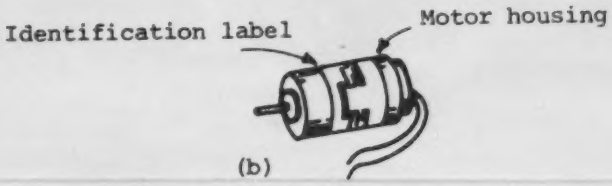
High-frequency inductors. (a) Loop antenna. (b) Rod antenna. (c) Intermediate-frequency transformer. (d) Oscillator coil.







A complete relay with the corresponding schematic symbol.



Electric motors. (a) The leads receive an electrical input, while the drive shaft delivers a mechanical output. (b) Miniature type.

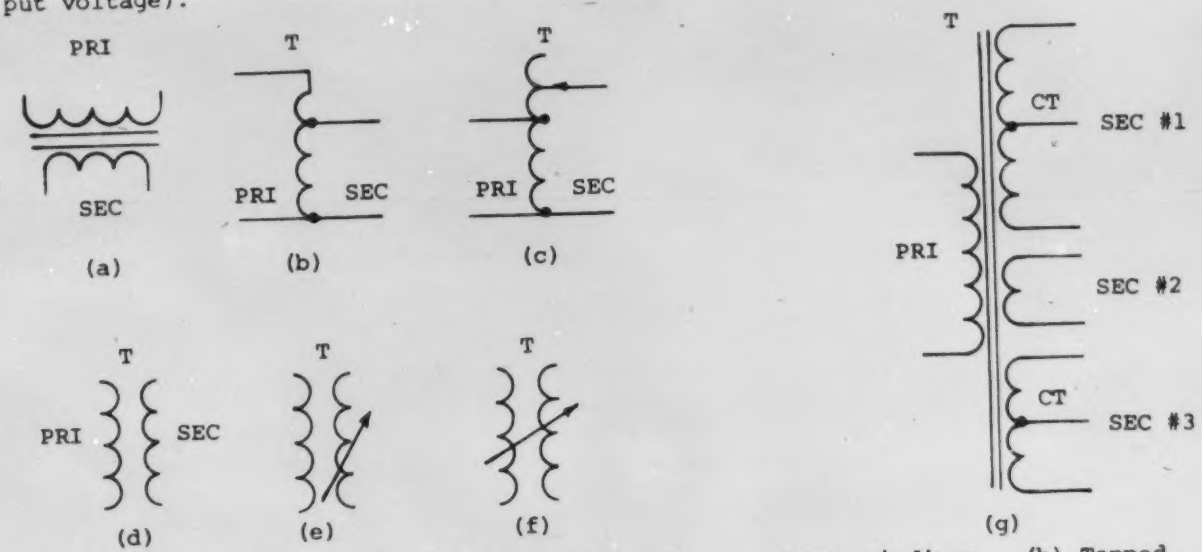
DC Inductors in general are designed to produce mechanical motion and thus convert electrical energy into mechanical energy.

AC Inductors are generally designed to modify or change characteristics of current and voltage in a circuit. AC inductors are also classified according to their operating frequency.

CAUTION: Never operate a high frequency inductor at a lower frequency.

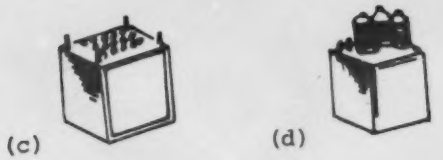
E. TRANSFORMERS

A transformer is a pair of coils wound together such that when current changes through one (the primary) the changing field produces a current in the other (the secondary). The ratio of the number of windings in the coils indicates whether the transformer is a "step-up" transformer (output voltage greater than input voltage) or a "step-down" transformer (output voltage less than input voltage).

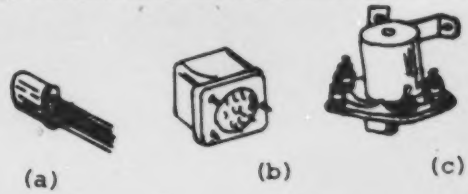


Transformer schematic symbols. (a) Iron core-two separate windings. (b) Tapped autotransformer. (c) Variable autotransformer. (d) Air core two separate windings. (e) Air core-one adjustable winding. (f) Air core variable coupling inbetween windings. (g) Multiple winding power transformer (iron core).

Metallic containers are frequently used for transformers to both keep the magnetic field confined and prevent a disruption by an outside magnetic field.



Low-frequency transformers. (a) Power Transformer. (b) Encapsulated. (c) Hermetically sealed. (d) High-voltage transformer.



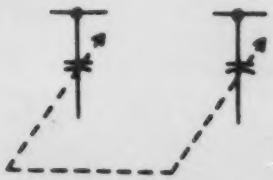
Relay cases, hermetically sealed. (a) Miniature. (b) Larger voltage and current capacity with hook terminals. (c) Heavy-duty power relay.

LABORATORY EXERCISE - INVESTIGATING TRANSFORMERS AND INDUCTORS

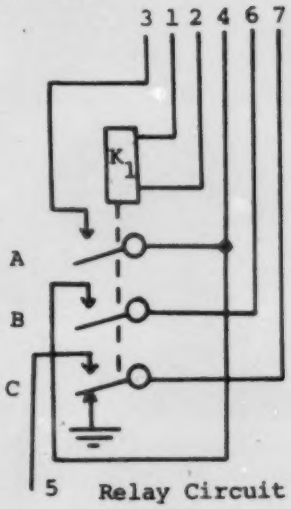
The student should be familiar with inductors and transformers. In particular the student should know the difference between a transformer and a choke, in what aspects the coil of a relay is similar to the coil of a choke, and what parts of an inductor are not included in their schematic symbols. The student should be able to describe what continuity tests could be made on inductors and transformers.

F. MECHANICAL CONNECTIONS

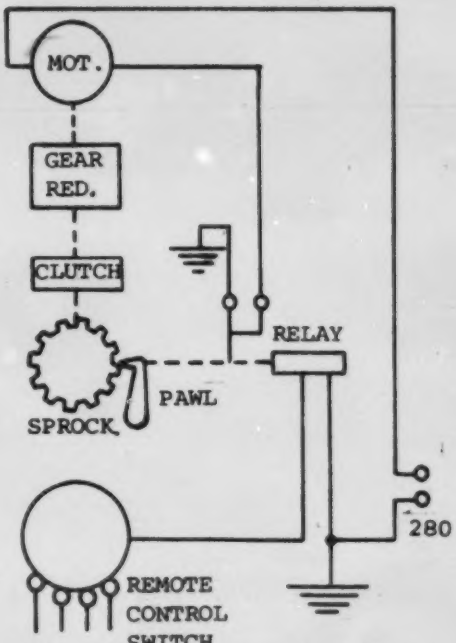
Often electro-mechanical systems are encountered where it is desirable to show both electrical and mechanical connections. On schematic drawings mechanical connections, enclosures, and shielded components are shown by broken lines.



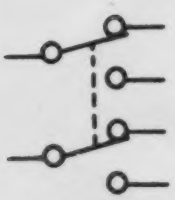
Ganged Capacitors



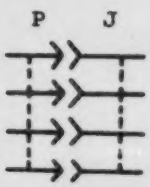
Relay Circuit



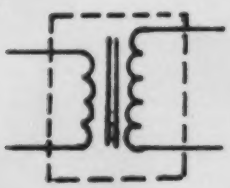
Autopositioner



DPDT Switch



Multiconductor



Enclosed Transformer

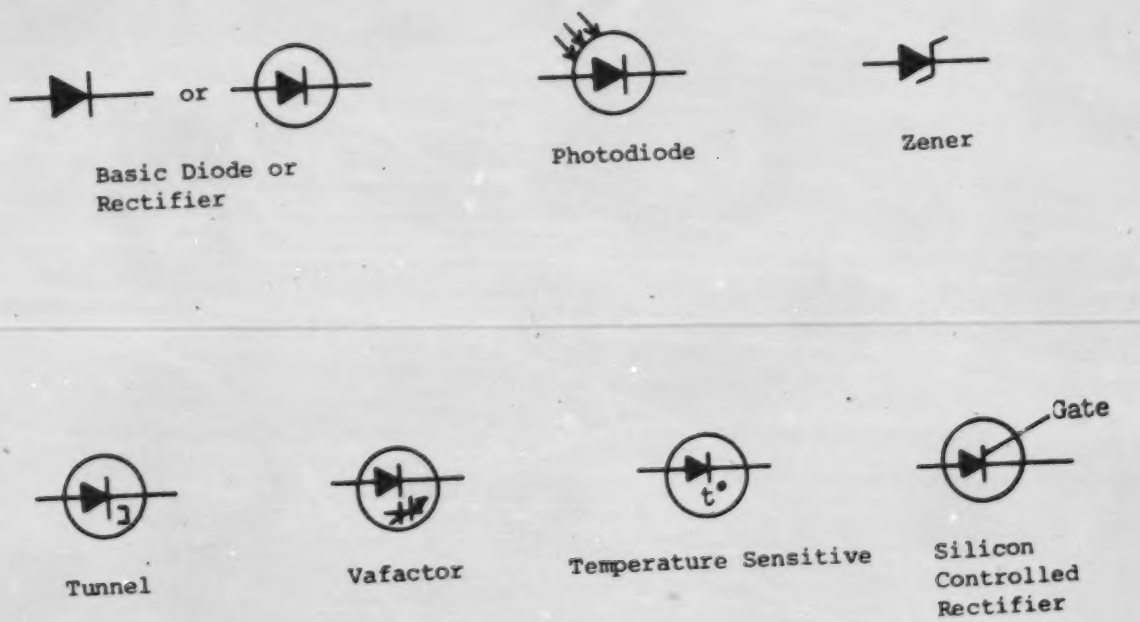
G. SEMICONDUCTOR DEVICES:

There are three broad classes of semiconductor devices which are referred to frequently as solid-state devices. These are the diode, transistor, and integrated circuit (IC) devices. Solid-state refers to the fact that these "active" devices contain contacts or junctions which are "fused" together with semiconducting materials such as silicon or germanium. There is no "gap" between electrodes such as are found in "vacuum tubes".

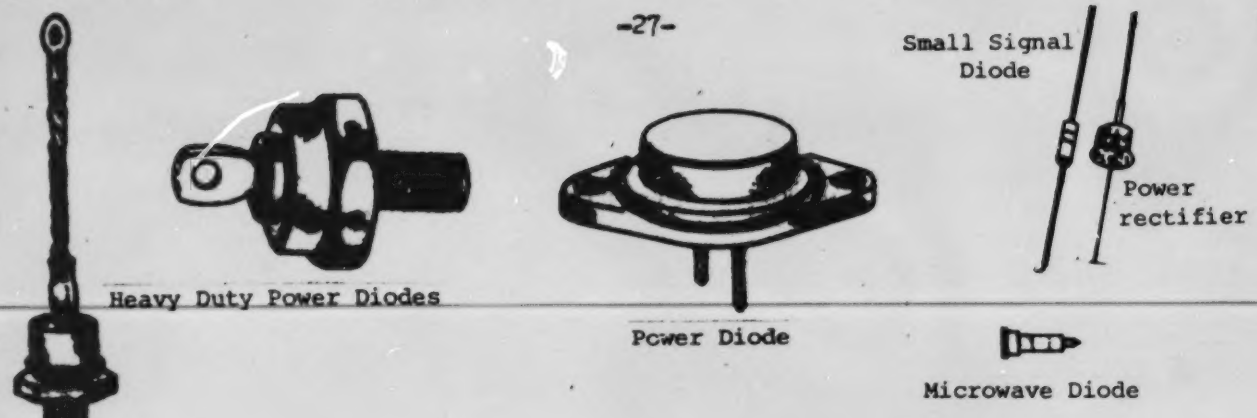
Semiconductor devices have now replaced all but a few "specialized" vacuum tubes. These solid-state devices are sometimes called "active" devices because they are used to control current flow in some prescribed manner.

1. Diodes:

One of the simpler semiconductor devices is the diode. There are a variety of these devices for controlling the direction of current flow, called rectifiers.



Diode Schematic Symbols



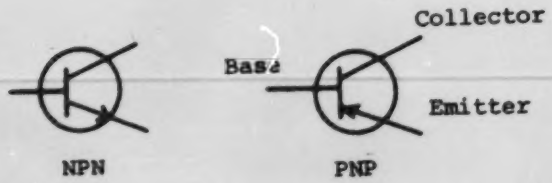
A few of the variety of sizes and shapes of diodes are shown above. Specifications for diodes usually call for a voltage (often a peak inverse voltage PIV) and a current rating.

LABORATORY

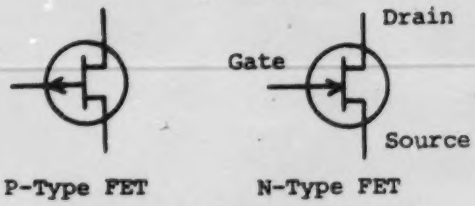
The student should have enough familiarity with semi-conducting diodes to be able to measure their resistance to determine if they are good or bad, to identify the anode and cathode, and to determine the allowed direction of current flow.

2. Transistors:

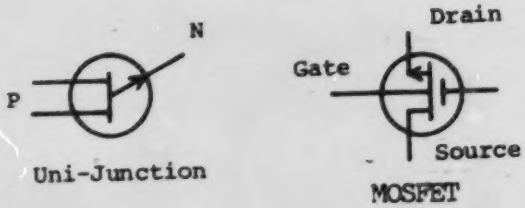
A transistor is a combination of several semi-conductor crystals bonded together. It serves as an electronic device for amplification and/or control. Transistors come in a variety of shapes and sizes. Except for very specialized devices for handling power and high frequencies, "transistorized" circuits are being packaged in micro-miniature devices called integrated circuits. Power transistors which may control large currents must be used with heat sinks to conduct heat away from the solid-state junctions of dissimilar semiconductors and metallic contacts.



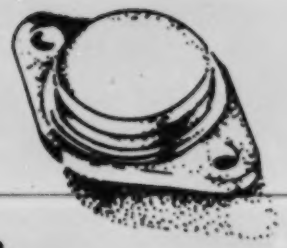
Basic Transistors

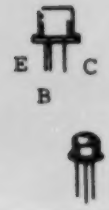


Field Effect Transistors

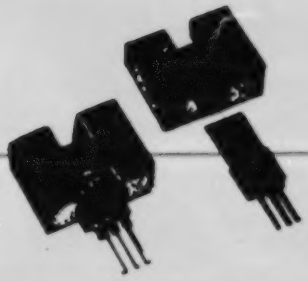


Transistor Schematic Symbols

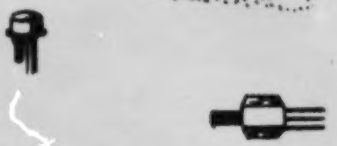




Small Signal Transistors

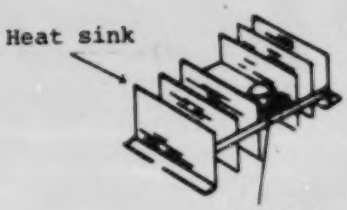


Power Transistors with Heat Sinks



Power Transistors

Heat Sinks



Power output transistor

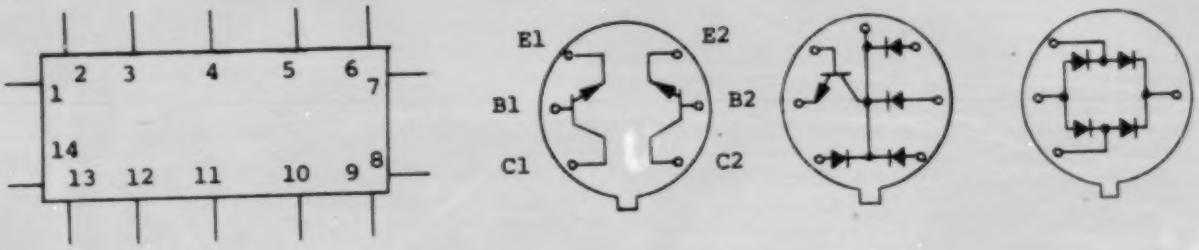
When specifying transistors, several parameters must be considered. Some of these are short-circuit current transfer ratio, cut-off frequency, input and output impedances, voltage, and temperature.

LABORATORY

The student should have some familiarity with transistor leads and configurations. Specifically, the student should be able to make an outline drawing of the base of two different types of transistor packages identifying the emitter, base and collector leads for each. He/she should be able to explain the "key" found on most TO-5 transistor packages, to name three materials used in the construction of transistors and to know the advantages and disadvantages of using sockets with transistors.

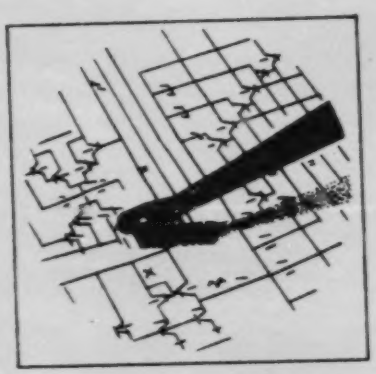
3. Integrated Circuits

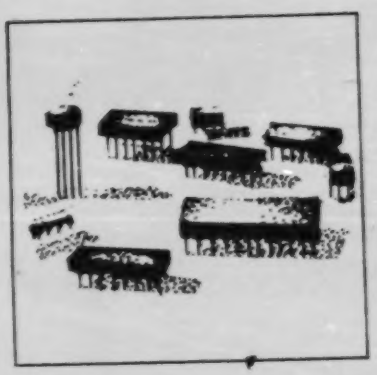
IC's are solid state devices since there is no gap between materials and electrodes or contacts. They are the fastest growing circuit devices being developed today. They are not simple, "discrete" components like the ones presented thus far. Symbols vary widely, but generally are simple outlines or blocks with the device number and letters presented as determined by the manufacturer.



Integrated Circuit Schematic Diagrams

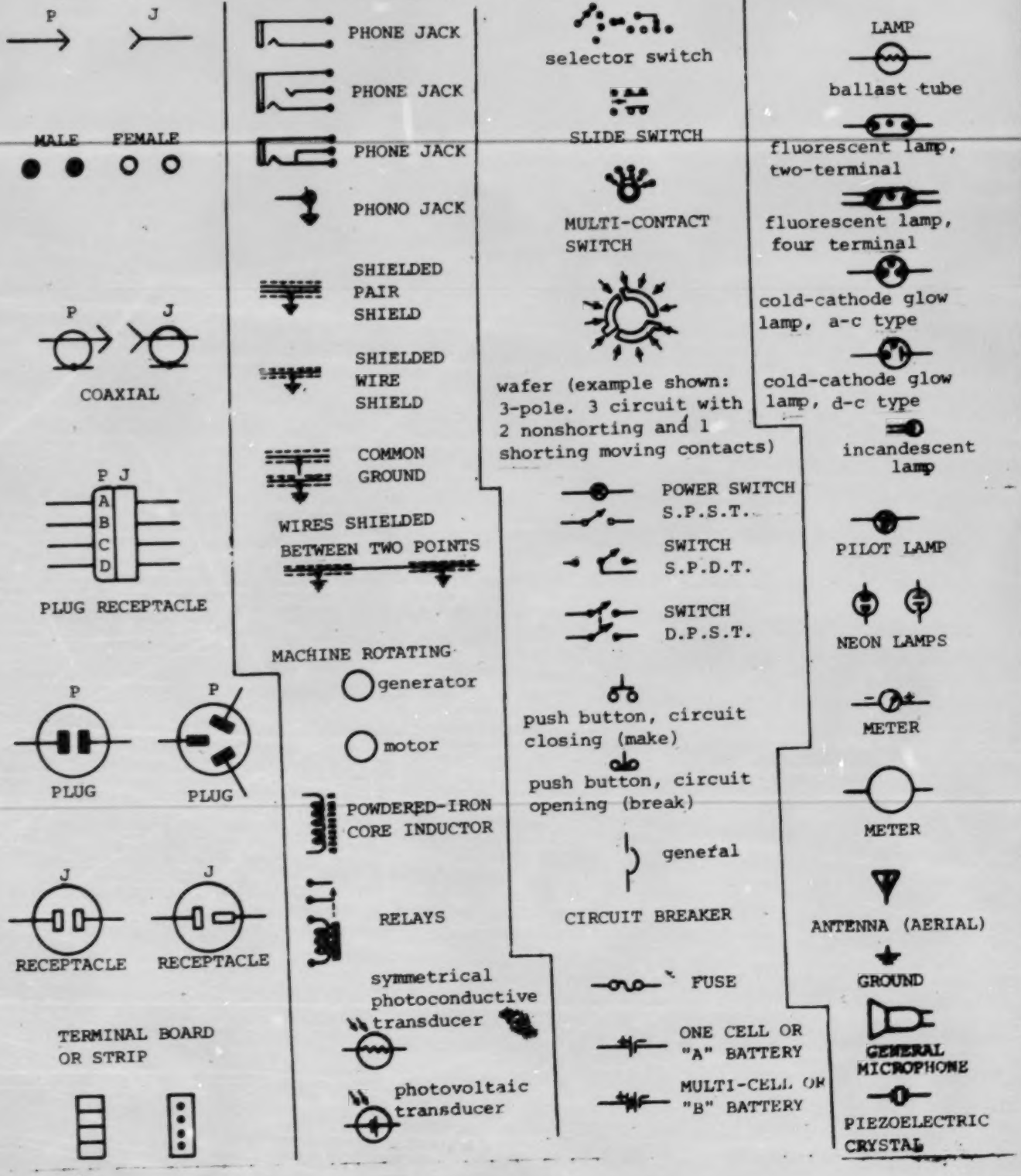
As the technology of IC's continues, it becomes less important to show the detailed circuits within. It is within reason now to purchase an LSI (Large Scale Integrated circuit) which can perform almost any desired circuit function. Discrete components such as transistors, capacitors, resistors and diodes are losing ground to the "microminiature" solid-state devices.





H. Schematic Symbols

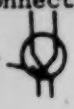
We have seen thus far only a few varieties of perhaps a hundred or so schematic symbols. Shown below are a few more of the more frequently used symbols.



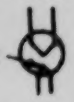
THERMOCOUPLE

general

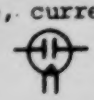
with integral heater internally connected

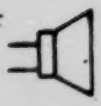
heater 

with integral insulated heater

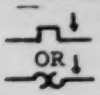
heater 

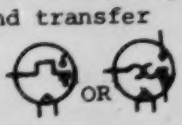
semiconductor thermocouple, temperature measuring

semiconductor thermocouple, current measuring 

Loudspeaker 

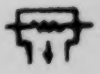
THERMOSTAT

thermostat with make contact 

thermostat with integral heater and transfer contacts 

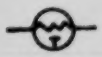
SQUIB

explosive

igniter 

sensing link

THERMISTOR

general 

with integral heater

VACUUM TUBES

3-Element Vacuum tube (triode)

pentode

twin triode equipotential cathode

cold-cathode voltage regulator

vacuum phototube

multiplier phototube

x-ray tube with control grid

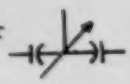
x-ray tube with grounded shield

double-focus x-ray tube with rotating anode

cathode-ray tube, electrostatic deflection

cathode-ray tube, magnetic deflection

CAPACITORS

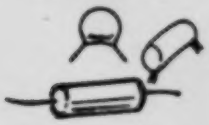
split stator 

dual electrolytic

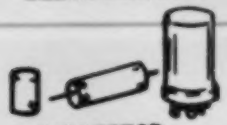
LABORATORY

The student should be able to identify electronic hardware. For example, he/she should be able to draw the schematic symbol for the following components:

CAPACITOR



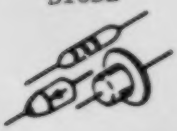
CAPACITOR, ELECTROLYTIC



CAPACITOR, VARIABLE

CRYSTAL, PIEZOELECTRIC

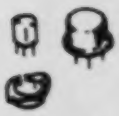
DIODE



INDUCTOR

JACK, PHONO

TRANSISTOR



TRANSFORMER, ADJ. POWDERED IRON CORE

LAMP BULB, NEON

LAMP BULB, ILLUMINATING

METER

RESISTOR

RESISTOR, ADJ. (POTENTIOMETER)

SWITCH, SPST OR DPDT

SWITCH, ROTARY

TRANSFORMER, IRON CORE

POWER TRANSFORMER

J. Reference Designations

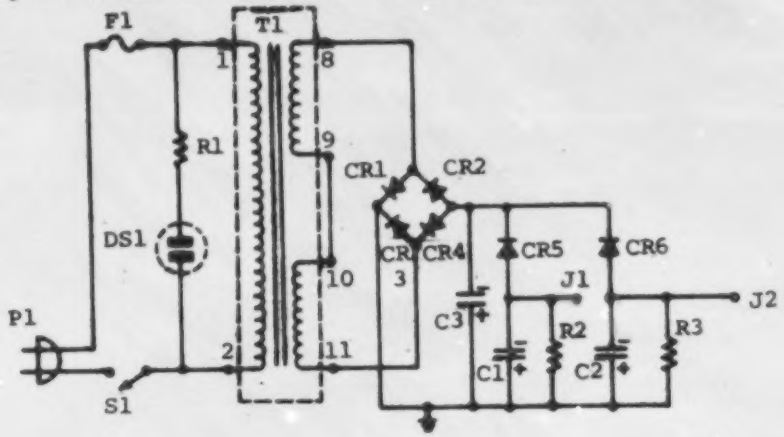
To help recognize schematic symbols and to be able to list components on a parts list, components are usually assigned a letter and number. The following list gives some of the more commonly used letters used to designate components.

Commonly accepted names are lower case; names that are standard items in Federal service are capital letters.

accelerometer	A
ADAPTER, CONNECTOR	CP
alarm	DS
amplifier (except rotating)	AR
AMPLIFIER, MAGNETIC (except rotating)	AR
amplifier, rotating (regulating generator)	G
ANTENNA	E
ARRESTER, LIGHTNING	E
assembly	A
ATTENUATOR (FIXED OR VARIABLE)	AT
audible signalling device (BUZZER; RINGER; TELEPHONE SIREN; SOUNDER, TELEGRAPH	DS
auto-transformer	T
Ballast tube or lamp (RESISTOR, CURRENT-REGULATING)	RT
barrier photocell	V
battery	BT
bimetallic strip	E
block, connecting (TERMINAL BOARD)	TB
blocking layer cell	C
blower (FAN, CENTRIFUGAL)	B
BRUSH, ELECTRICAL CONTACT	E
BUS BAR	W
cable, cable assembly (with connectors)	W
capacitance bushing	C
CAPACITOR	C
CAVITY, TUNED	Z
cell, battery	BT
cell, light-sensitive, photo-emissive (PHOTOELECTRIC CELL)	V
choke coil	L
CHOPPER, ELECTRONIC	G
CIRCUIT BREAKER	CB
coil, hybrid	HY
COIL, RADIO FREQUENCY	L
COIL (all others not classified as transformers)	L
COMPUTER	A
CONNECTOR, PLUG, ELECTRICAL	P
CONNECTOR, RECEPTACLE, ELECTRICAL	J
CONTACT, ELECTRICAL	E
contactor (manually, mechanically, or thermally operated)	S
contactor (RELAY, ARMATURE; RELAY, SOLENOID)	K
converter (rotating machine)	MG
CORE, ADJUSTABLE TUNING; CORE, ELECTROMAGNET; core, inductor; core, memory; core, transformer	E
COUNTER, ELECTRICAL	M
COUNTERPOISE, ANTENNA	E
COUPLER, DIRECTIONAL	DC
coupling (aperture, loop, or probe)	CP
crystal detector (SEMICONDUCTOR DEVICE, DIODE)	CR
crystal diode (SEMICONDUCTOR DEVICE, DIODE	CR
crystal diode, breakdown	VR
crystal unit (SEMICONDUCTOR DEVICE, DIODE)	CR
crystal unit, piezoelectric (CRYSTAL UNIT, QUARTZ)	Y
cutout, fuse (FUSE CUTOUT)	F
cutout, thermal	S
DELAY LINE	DL
detector, crystal (SEMI-CONDUCTOR DEVICE, DIODE)	CR
device, indicating (INDICATOR) except meter or thermometer	DS
dipole antenna (ANTENNA)	E
disconnecting device (connector, receptacle)	J
disconnecting device (connector, plug)	P
disconnecting device (switch)	S
discontinuity (usually co-axial or wave-guide transmission)	Z
DYNAMOTOR	MG
ELECTRON TUBE	V
equalizer (NETWORK, EQUALIZER)	EQ
FACSIMILE SET	A
fan	A
filter	FL
flasher (circuit interrupter)	DS
frame	MP
frequency changer (rotating)	G
FUSE	F
FUSEHOLDER	X
GAGE (meter; thermometer; strain gage)	M
gap (horn, protective, or sphere)	E
GENERATOR	G
GYROSCOPE	MP
Hall effect device	E
HANDSET	HS
hardware (common fasteners, etc.)	H
head (ERASER, MAGNETIC; HEAD, SOUND; with various modifiers)	FU
HEADSET, ELECTRICAL	HT
HEATER	HR
HORN	LS
hydraulic part	MP
INDICATOR (except meter or thermometer)	DS
inductor	L
instrument	M
INSULATOR	E
interlock, mechanical	MP
interlock, safety, electrical	S
inverter (MOTOR-GENERATOR)	PS
isolator	AT
jack	J
junction (coaxial or wave-guide)	CP
junction, hybrid	HY
KEY, TELEGRAPH	S
LAMP, FLUORESCENT	DS
LAMP, GLOW	DS
LAMP, INCANDESCENT	DS
lamp, pilot (LAMP, INCANDESCENT; LAMP, GLOW)	DS
lamp resistance	RT
lamp, signal (LAMP, INCANDESCENT; LAMP, GLOW)	DS
LAMPHOLDER	X
line, artificial	Z
line, delay (DELAY LINE)	DL
Idop antenna (ANTENNA)	E
LOUDSPEAKER	LS
MAGNET, PERMANENT	E
mechanical part	MP
meter	M
MICROPHONE	MK
mode suppressor	Z
mode transducer	MT
modulator	A
MOTOR	B
MOTOR-GENERATOR	MG
mounting (not electrical circuit, not a socket)	MP
neon lamp (LAMP, GLOW)	DS
NETWORK, HYBRID CIRCUIT	HY
network, general (where specific class letters do not fit)	Z
oscillator (excluding electron tube)	Y
oscillator, magnetostriction	Y
OSCILLOGRAPH	M
OSCILLOSCOPE	M
pad (ATTENUATOR, FIXED)	AT
part, miscellaneous electrical	E
part, miscellaneous mechanical (bearing, coupling, gear, shaft, etc.)	MP
part, structural	MP

phase shifting network (NETWORK, PHASE-CHANGING)	S
phototube (PHOTOELECTRIC CELL)	V
pickup; erasing head; recording head; reproducing head	PU
plug, electrical (CONNECTOR, PLUG, ELECTRICAL)	P
POST, BINDING	E
potentiometer (RESISTOR, VARIABLE)	R
POWER SUPPLY	PS
REACTOR (iron core)	L
RECEIVER, RADIO	RE
receiver, telephone headset (HEADSET, ELECTRICAL)	HT
receptacle (connector, stationary portion)	J
recorder, elapsed time	M
RECORDER, SOUND	A
recording unit	A
rectifier (SEMICONDUCTOR DEVICE, DIODE)	CR
rectifier (complete power supply unit)	PS
reed, vibrating	MP
REGULATOR, VOLTAGE (excludes tube regulators)	VR
relay (RELAY, ARMATURE; RELAY, SOLENOID; relay, reed; relay, solid-state)	K
REPEATER, TELEPHONE	AR
REPRODUCER, SOUND	A
resistive termination	AT
RESISTOR	R
RESISTOR, CURRENT REGULATING	MT
RESISTOR, THERMAL (thermistor)	R
RESISTOR, VARIABLE	R
RESISTOR, VOLTAGE SENSITIVE	RV
resolver (SYNCHRO, RESOLVER)	B
resonator (CAVITY TUNED)	Z
RHEOSTAT	R
rotary joint (microwave)	E
SATURABLE REACTOR	L
selenium cell (rectifier)	CR
sensor (transducer to electric power)	A
shield, electrical	E
shifter, phase (NETWORK, PHASE-CHANGING	S
short (coaxial transmission)	E
SHUNT, INSTRUMENT	R
slip ring (RING, ELECTRICAL CONTACT)	SR
socket	X
solenoid (SOLENOID, ELECTRICAL)	L
speaker (LOUDSPEAKER)	LS
SQUIB, ELECTRIC	SQ
squib, explosive	SQ
strip, terminal (TERMINAL BOARD)	TB
structural part	MP
subassembly	A
SWITCH	S
SWITCH, INTERLOCK	S
SYNCHRO	B
taper, coaxial or wave-guide	T
TELEPRINTER	A
TELETYPEWRITER	A
TERMINAL (individual)	E
TERMINAL BOARD	TB
termination, resistive	AT
test block	TB
test point (not actually a reference designation)	TP
thermistor	RT
THERMOCOUPLE	TC
thermo generator	PS
THERMOSTAT	S
timer, electric	M
transducer	MT
transducer, mode	MT
TRANSFORMER	T
TRANSISTOR	Q
transmission path	W
TRANSMITTER, RADIO	TR
tuned circuit	Z
varistor, symmetrical (RESISTOR, VOLTAGE SENSITIVE)	RV
varistor, asymmetrical (SEMICONDUCTOR DEVICE, DIODE; rectifier, metallic)	CR
VIBRATOR, INTERRUPTER	G
visual signalling device	DS
voltage regulator (REGULATOR, VOLTAGE)	VR
WAVE GUIDE	W
WAVE-GUIDE FLANGE (plain)	P
WAVE-GUIDE FLANGE (choke)	J
WINDING	L
WIRE OR CABLE	W

The student should be able to identify schematic symbols. For example, given the power supply schematic below he/she should identify each component.



P1 _____ CR1 _____ C1 _____

F1 _____ CR2 _____ C2 _____

T1 _____ CR3 _____ C3 _____

DS1 _____ CR4 _____ R1 _____

S1 _____ CR5 _____ R2 _____

J1 _____ CR6 _____ R3 _____

J2 _____

The student should also be able to identify electronic hardware by performing the following:

1. Using the catalog provided, give the physical dimensions for a 1 watt carbon resistor.

2. Using the catalog provided, find the cost (per each) for a DP3T slide switch if you purchase in quantities of 200 switches.

3. List two manufacturers for each of the following components.

   Resistors

   Capacitors

   Connectors

   Transistors

   Transformers

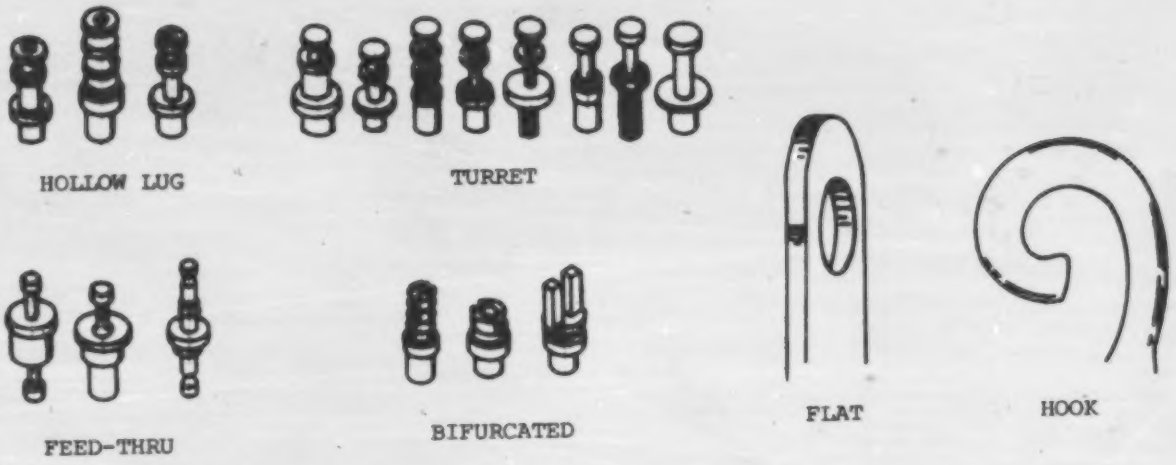
4. List all the information found on the smallest (subminiature) rf inductor with a 0.75 micro-henry value.

5. From the catalogue provided, list some of the uses of potting materials.

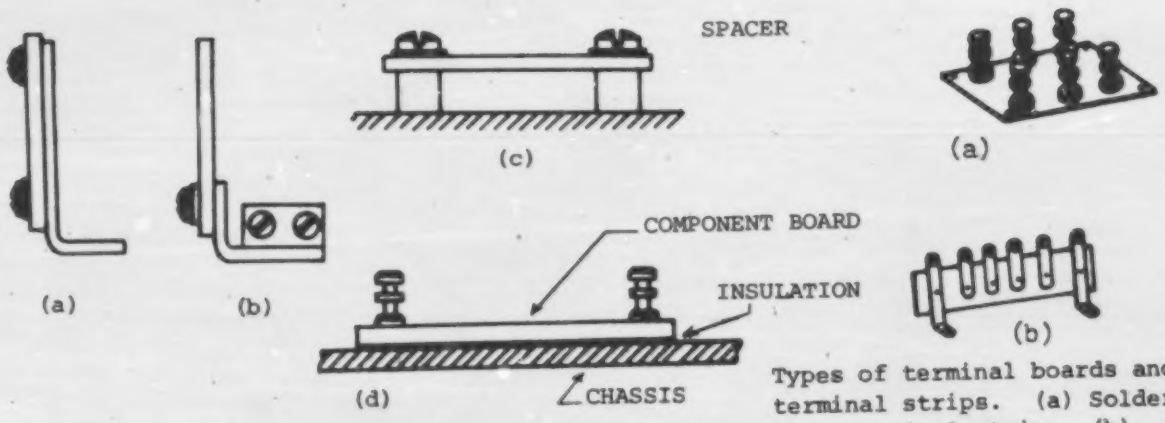
K. Terminals and Connections

There are many terminals and types of connections used to assemble electronic components.

1. Solder terminals



Terminal styles for component boards.



Board mounting methods.
(a) Plain bracket. (b) Special bracket.
(c) Spacer. (d) Insulation plate.

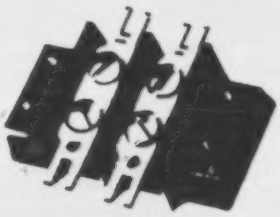
Types of terminal boards and terminal strips. (a) Solder-type terminal strip. (b) Terminal board.

All of the above terminals hold electronic components in place by soldering their leads in place.

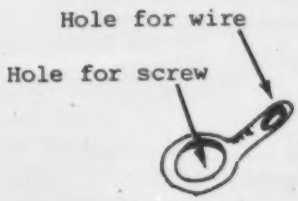
2. Solderless Terminals

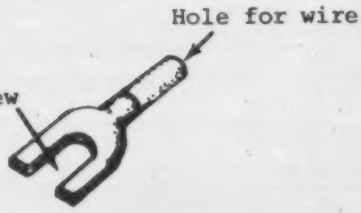
As the name implies, solderless terminals do not require soldering. Examples of solderless terminals are shown below.

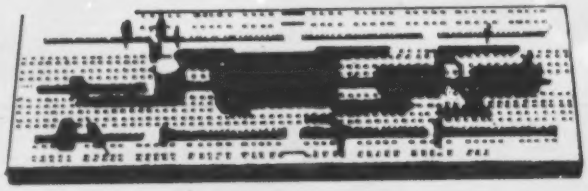
Screw Terminals



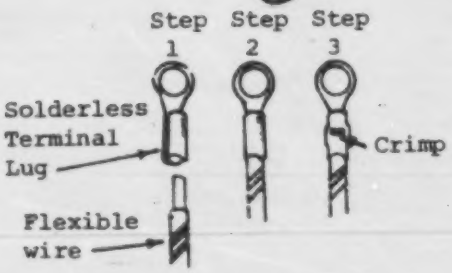
Rarely are wires simply connected to screw type terminals. They usually are crimped to a terminal lug.



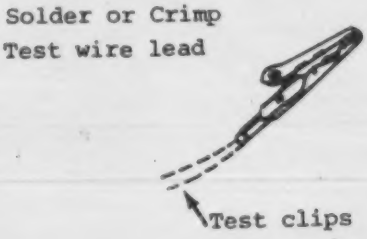




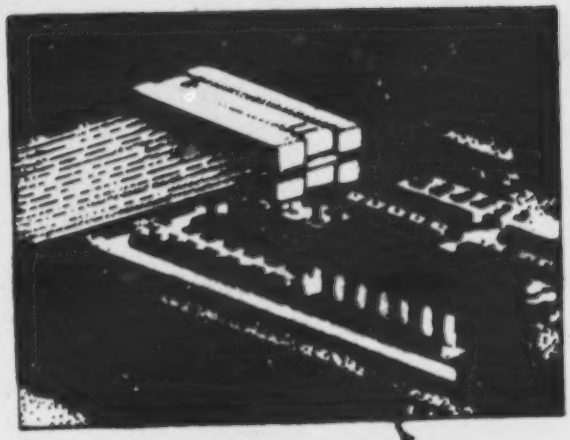
For rapid assembly and bread-boarding, plug-in boards are very valuable time savers.

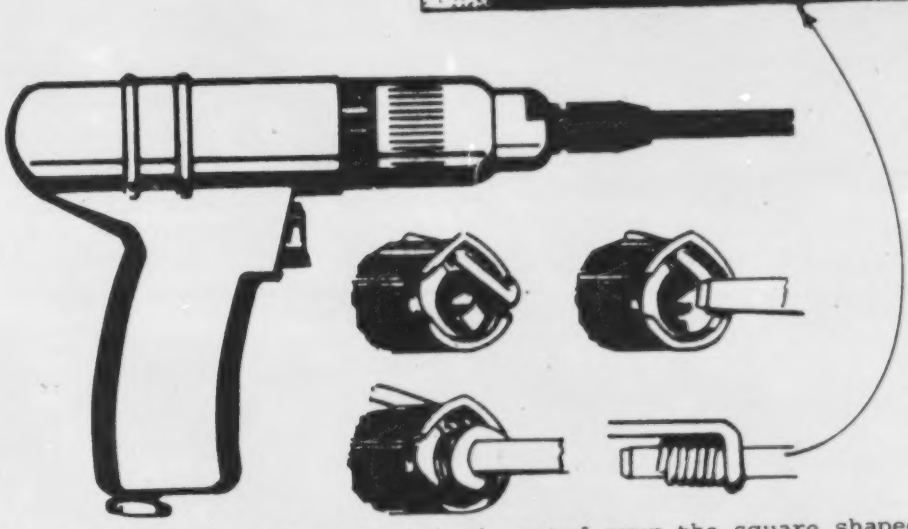


The use of a crimping tool.

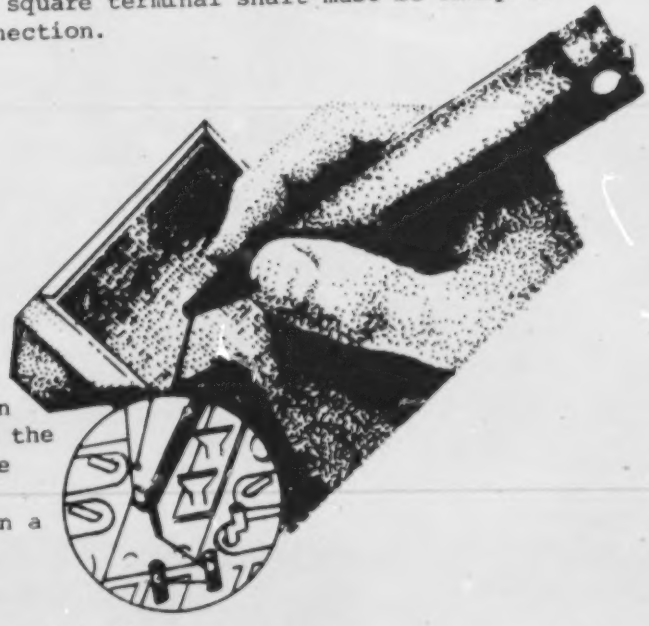


Wire-wrap is now a fairly widely used method for making several permanent connections in a very compact space. Shown at the right is an assembly that makes maximum use of solderless connections.





Wire-wrap tool showing how end of tool is inserted over the square shaped terminal. At least two corners of the square terminal shaft must be sharp to "bite" into the wire for a good connection.



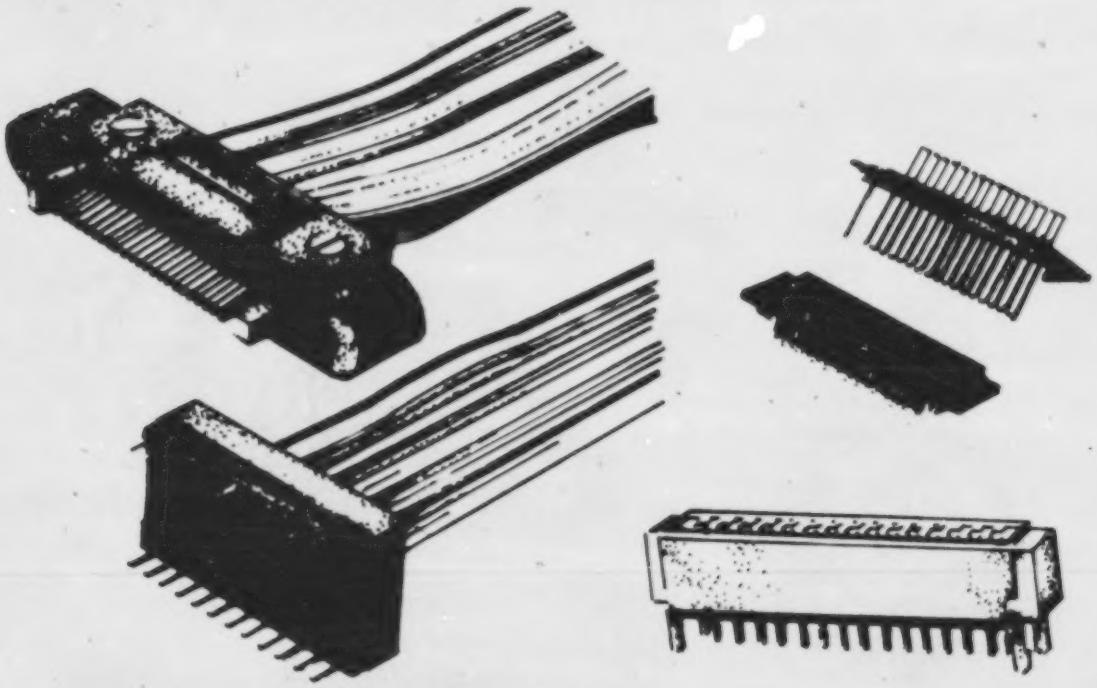
We can expect to see more new tools on the market every year for speeding up the process of making connections. On the right is a new tool called a "Wiring Pencil" for making fast connections on a breadboard.

LABORATORY

The student should know how to make a solderless connection using a crimping tool. He/she should know advantages and disadvantages of using solderless terminal lugs, 4 types of solder materials, and what is wire wrapping.

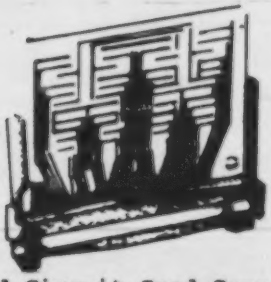
3. Semipermanent Connections - Cable Connectors

When semipermanent connections are desired between major units of electronic equipment, connectors of the types to follow are of great value. The variety often seems endless like all other components of electronic hardware.



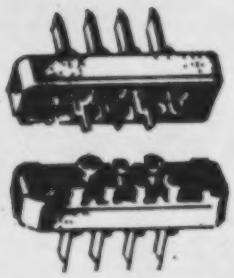
Flat Cable Connectors

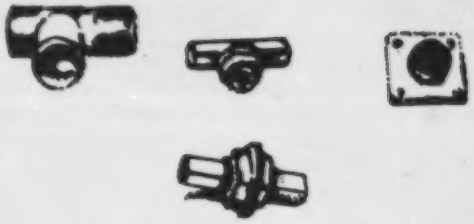
Plugs & Jacks



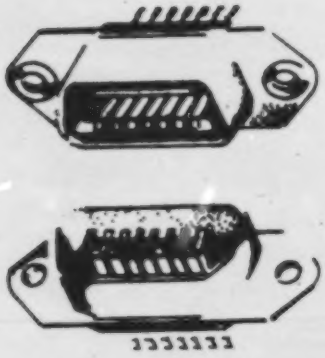
Printed Circuit Card Connector

Miniature Connector

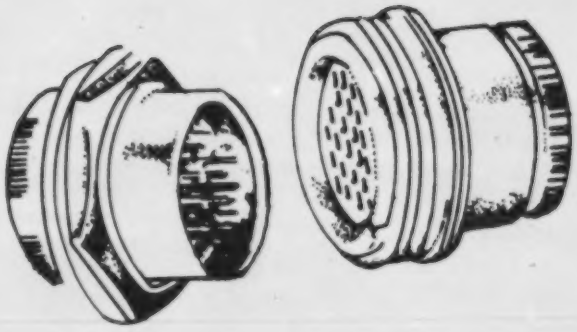




Coaxial Connectors



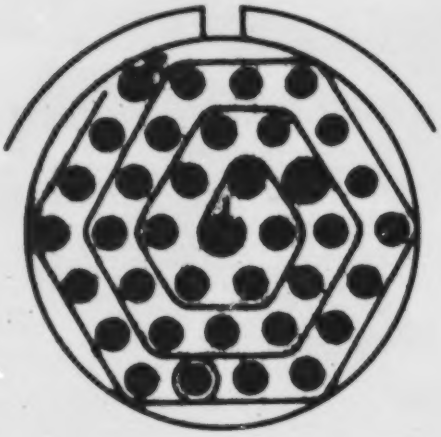
Rack and Panel



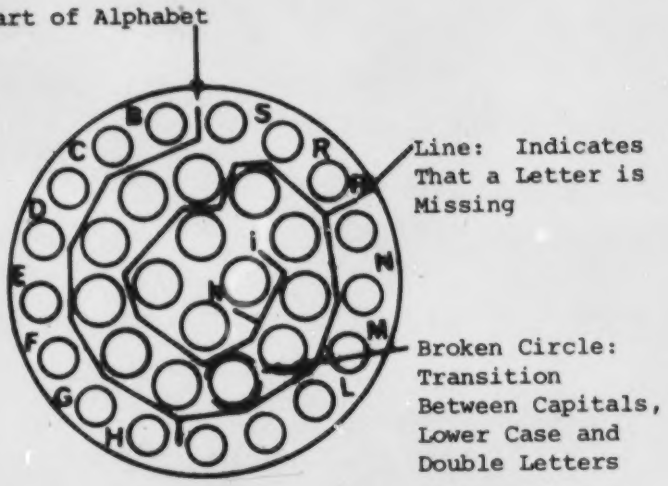
Miniature Connectors

The characteristic of "push-pull" coupling to facilitate making and breaking make the use of these type of connectors very convenient.

Identifying the pins in miniature connectors requires a word of explanation. Note the diagrams below.



The Ever-Expanding Orbital Sequential Numbering System


Start of Alphabet
Line: Indicates That a Letter is Missing
Broken Circle: Transition Between Capitals, Lower Case and Double Letters

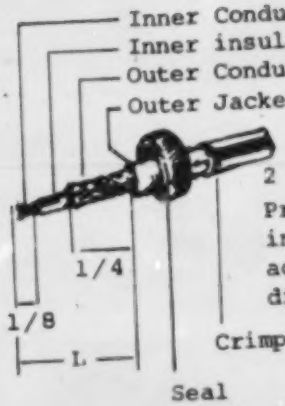
Typical Diagram of Alphabet Identification

Connector failures of the minature connectors are relatively infrequent, but when they do occur it is usually because the contacts are not properly seated (locked) into place.

The assembly of connectors with individual pins and mating contacts is gradually giving way to the flat cable and compatible connectors with permanent contacts that are mated (connected) to the flat cable wiring by means of a special tool. The tool forces away the wire insulation and makes contact with the wire inside the connector. Unfortunately, any change in wiring must be made on the opposite side of the flat cable connector - within the unit being connected.

Assemblying Coaxial Connectors:

Place the crimping sleeve "B" and the seal retainer nut "A" over the coaxial cable.



Prepare the coaxial cable in the manner illustrated, according to the indicated dimensions.

Note: Use of hot wire stripper is recommended.

L	9/16 on all cables up to .110 overall dia.
	11/16 on all cables larger than .115 overall dia.

3.

Place the center contact in the crimping tool. Insert the center conductor of the cable in the contact crimp barrel so that the insulation touches the back of the contact and compress the crimping mechanism, completing the crimp cycle. The crimp tool is designed so that the contact will not be released until a complete and perfect crimp has been made.

4.

Two series of 4 indents secure the center contact to the inner conductor of the coaxial cable with a strength exceeding that of the cable itself.

5.

Push the crimp protection sleeve "C" over the crimped center contact and under the exposed portion of the outer conductor of the cable.

6.

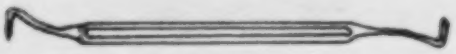
Push the Teflon sleeve "D" over the crimped contact and past the contact ridge. To accomplish this, hold the contact front and push the sleeve slowly into its position.

7.

Insert the entire assembly through the back of the connector shell and tighten the seal retainer nut "A". This will permit automatic alignment of the inner conductor.

The eraser is valuable in cleaning contacts on printed circuits and other "exposed" contacts or terminals. The knife is useful in cutting or scraping materials where the diagonal cutter does not seem to fit the job. A pair of toe-nail clippers are found in the tool box of experienced electronic technicians. They are used to clip small wires - especially the excessive lead lengths on component wires when mounting on printed circuit boards.

The soldering aid is used to hold a wire or component lead in place while soldering or in removing a soldered connection. They may be purchased commercially; however, the best solder aids come from discarded dental tools.



DENTAL TOOL

Dental tool soldering aid. The thin curved ends are ideal for holding something in place while soldering or prying up leads when unsoldering

Other valuable specialized tools are needed for specific jobs. The heat gun shown is used for attaching heat shrinkable plastic tubing to exposed connections. Special heat shrinkable connections are now available for use where crimping was formerly used. The special holding fixture or vise shown will hold a printed circuit card in almost any position to make it easier to repair or modify a circuit.

Holding Vise

Variable Heat Soldering Iron

Heat Gun

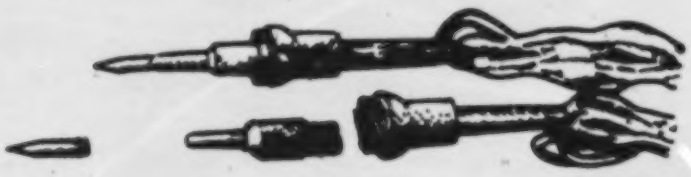
The variable heat soldering iron is useful when a variety of soldering requirements are encountered. The required heat is dialed and in a short time soldering can begin on either miniature or large terminals and connections.

M. Soldering Irons

A large selection of soldering irons is available. The correct type of soldering iron depends upon the soldering task. Soldering irons are primarily rated according to wattage or the amount of heat they produce. For convenience they are produced in "pencil","pistol grip" (gun),or an O "wand" with fairly large handle. The pencil and gun type soldering irons are preferred and perhaps more convenient for small electronic equipment.

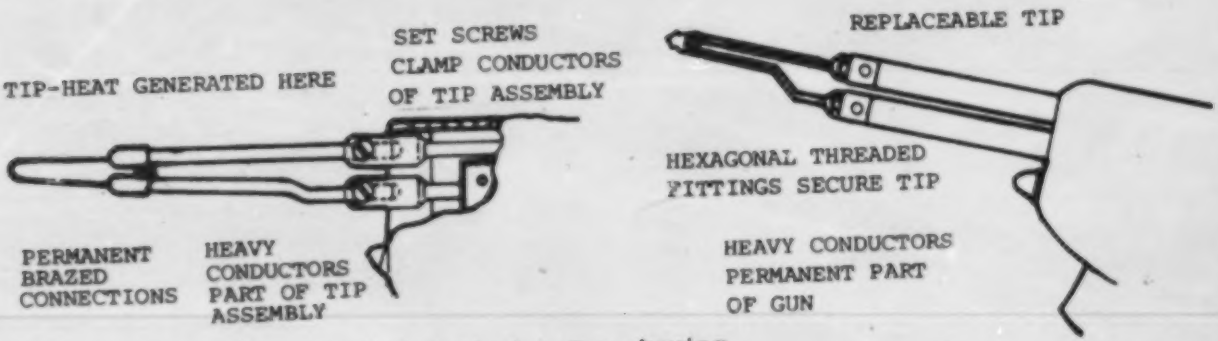
The wattage rating is of primary importance because just the right amount of heat for the soldering test is very important. Too much heat may damage components being soldered. Too little heat may take too long to melt the solder and again damage the component being soldered because of time which may become sufficiently long as to conduct too much heat into the electronic component.

As a general rule, the wattage rating for soldering a number 20 AWG wire to the variety of solder terminals shown earlier should not be higher than 50 watts. Smaller terminals and smaller diameter wires will require less heat. Printed circuit boards containing discrete components such as transistors, capacitors, resistors, diodes, etc., should never be exposed to heat in excess of 25 watts for more than about 5 seconds. The smaller connections for integrated circuits (IC) may require only a 10 or 15 watt soldering iron. At these lower wattage ratings the pencil type iron is preferred because of the close proximity to adjacent connections and control of the iron itself which is much easier.



Tip Heating Element Handle with protection from heat.

The Soldering "Pencil" Iron showing replaceable parts.


TIP-HEAT GENERATED HERE
SET SCREWS CLAMP CONDUCTORS OF TIP ASSEMBLY
PERMANENT BRAZED CONNECTIONS
HEAVY CONDUCTORS PART OF TIP ASSEMBLY
REPLACEABLE TIP
HEXAGONAL THREADED FITTINGS SECURE TIP
HEAVY CONDUCTORS PERMANENT PART OF GUN

The Soldering Gun showing replaceable tips.

The use of the soldering gun should be limited to temporary repairs of larger components and connections.

The shape of the tip of a soldering iron is determined by the type or shape of connection being soldered. As a rule the shape of the tip should be one that provides the greatest surface area of contact with the connection to be soldered. At the same time the tip should not be so large as to damage adjacent components or connections. A variety of tip shapes are presented below.

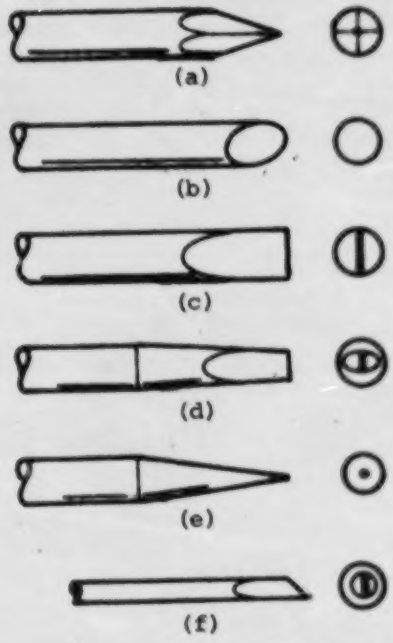


Fig. 14-3 Common soldering tip shapes.
(a) Pyramidal. (b) Beveled. (c) Chisel.
(d) Tapered chisel. (e) Conical. (f) Pointed chisel.

Tips of soldering irons are copper alloys and frequently plated with gold, iron or nickel to prevent oxidation of the copper. These tips should never be filed or sanded.

LABORATORY

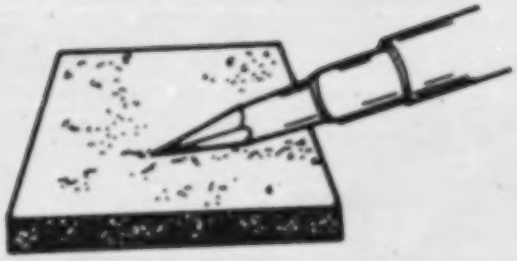
The student should be familiar with the use of typical soldering irons, and in particular should know the safety precautions associated with their use. He/she should know the relationship between power rating and heat necessary for a specific job.

N. Tinning

Tinning is defined as the spreading of a thin layer of molten solder alloy over a surface that has previously been cleaned and preheated.

The tip of the soldering iron must be tinned to permit the maximum transfer of heat from the tip to the joint or connection to be soldered.

Flux used in tinning is a plasticized resin or weak acid used to remove metal oxides from the surface of metals.



Use of a moist sponge to wipe the tip of a soldering iron.

Tinning the Soldering Iron Tip.

1. Lightly dampen a sponge.
2. Plug in the soldering iron and allow it to get hot.
3. Wipe the tip on the sponge.
4. Apply solder with a flux core to the tip.
5. Wipe the excess solder off on the sponge.
6. Inspect the tip. This process may have to be repeated several times to remove all the oxides from the soldering iron tip.
7. The soldering iron tip will be tinned when a smooth shiny film can be seen to cover the tip.

LABORATORY

The student should be able to tin a soldering iron. He/she should know why resin is used during tinning.

O. Soldering

Soldering is the process of uniting two clean metal surfaces with a thin layer of a third metal alloy. In this process the correct amount of heat, the application of a flux, and the type of solder must be considered.

For electronic equipment, the flux is a plasticized resin. The flux is necessary to remove metal oxides from the surfaces of the metals to be soldered. Never use an acid as a flux as it will eventually dissolve the copper conductor.

Solder is an alloy of tin and lead. For electronics, an alloy of 60% tin and 40% lead is normally used. For convenience, wire solder used today has an inner core of the resin flux. As the wire solder melts on the heated metal surfaces, the flux runs out ahead of the solder cleaning the surfaces so that the solder will penetrate the metal and form a good "joint" or connection.

The amount of solder used on a joint is as important as the fitting together of the two metals to be united. The diagrams illustrate the correct methods of soldering wires to terminals and to printed circuit solder connections.

Important aspects of soldering include having adequate work-space, good lighting and a well-ventilated room.

1. Soldering Defects:

COLD SOLDER: The connection appears dull, chalky, or crystallized as the result of insufficient heat or movement of the joint as it cools.

EXCESS SOLDER: The thickness of solder on the wire attached to the terminal should be no more than one-third the thickness of the wire. As a rule, the outline of the wire and terminal should be visible.

INSUFFICIENT SOLDER: This produces an uncertain union or connection of the metal parts and may not hold up under vibration.

RESIN CONNECTION: The metal parts may be joined only by the thin coat of flux even though sufficient solder has been applied, and thus will separate easily.

2. Wire Connections:

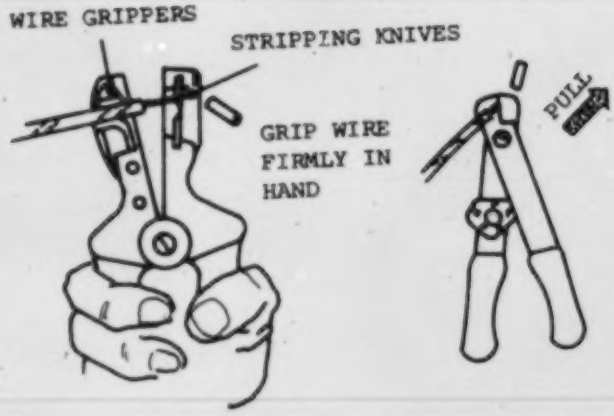
In removing the insulation from wires to be connected, it is important to "strip" the wire without damaging it.

There are essentially three major methods for stripping wires of their insulation:

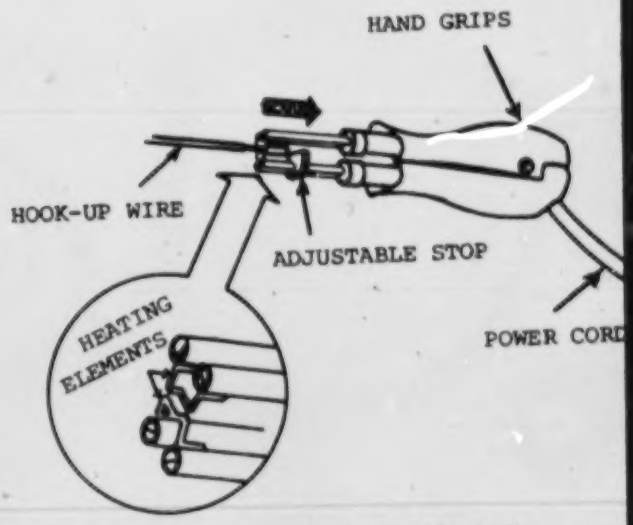
Mechanical - cutting the insulation and pulling it off the wire.

Thermal - heating and melting the plastic insulation to remove it from the wire.

Chemical - dissolving the insulation in a chemical solvent.

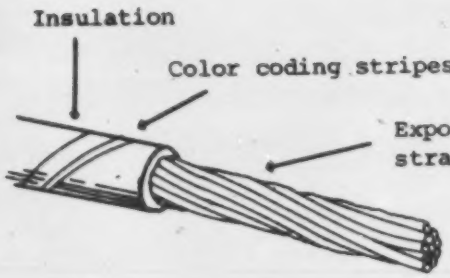


Examples of mechanical wire strippers.

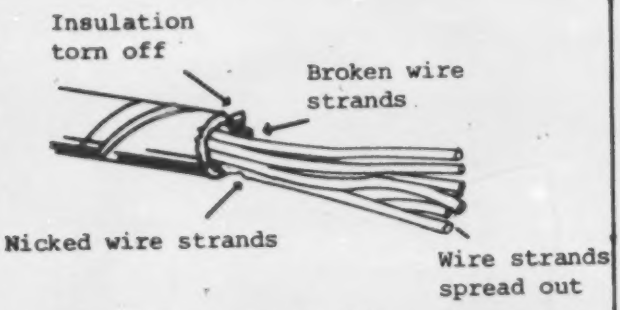


Thermal wire strippers.

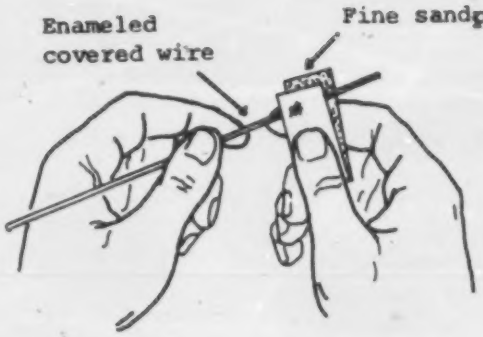
These will not nick the conductors.



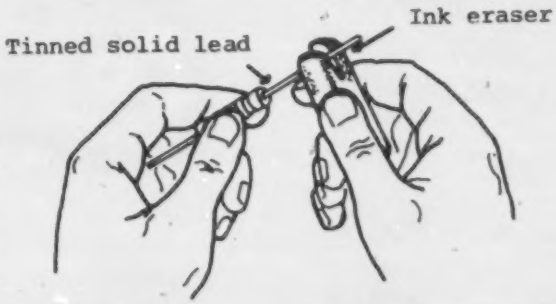
Correctly stripped wire



Incorrectly stripped wire

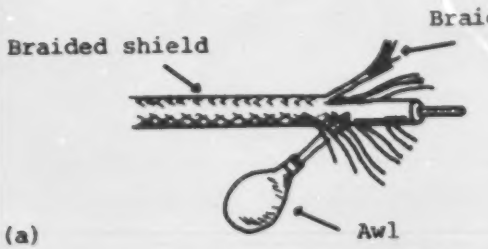


Removing enamel insulation.

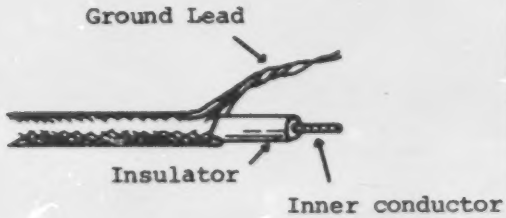


Cleaning component tinned leads.

Preparing Shielded Wires for Soldering

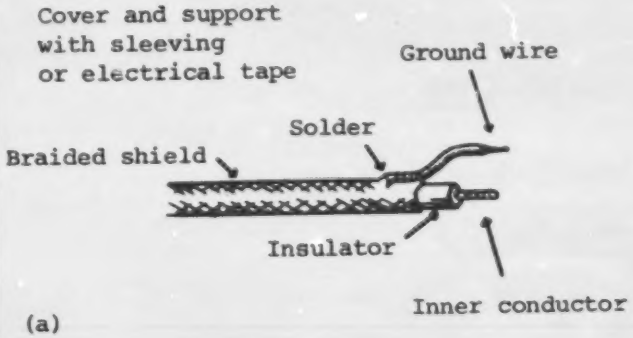


(a)

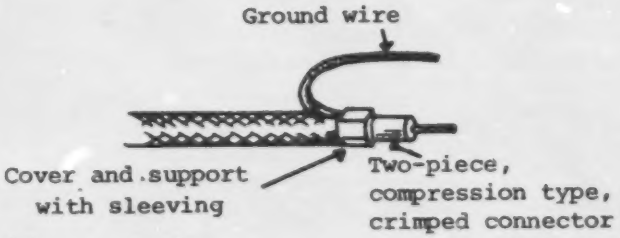


(b)

(a) Combing the braid strands.
(b) Use of the braid strands for the ground lead.

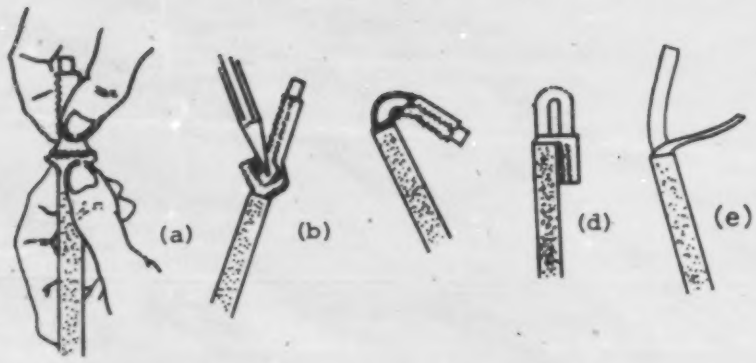


(a)



(b)

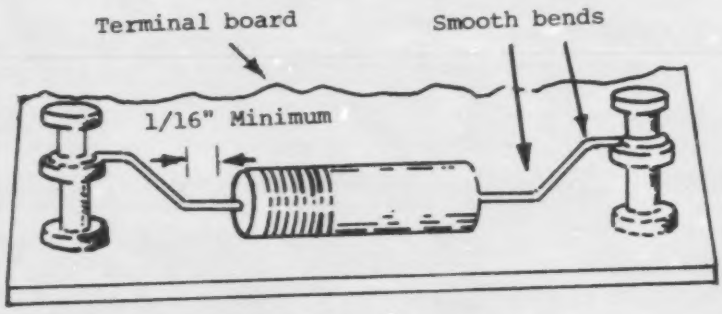
Attaching the ground wire. (a) Soldering the ground wire. (b) Crimping the ground wire.



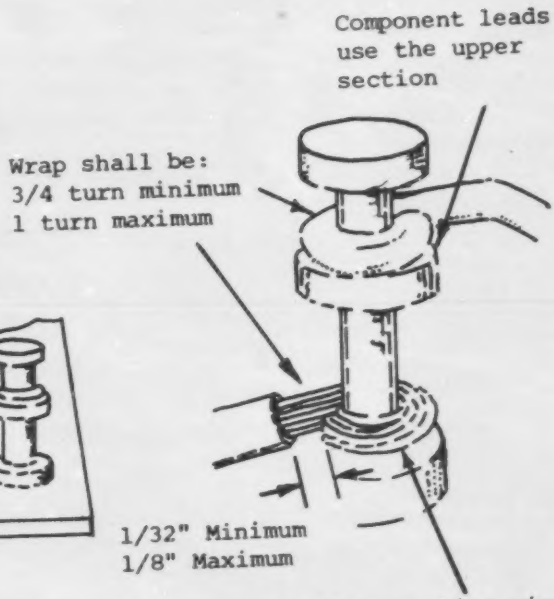
Stripping a shielded conductor by pulling out the center conductor through the shield. (a) Bunch the shield near the jacket. (b) Carefully open a hole where the shield has been gathered. (c) Bend the wire as shown. (d) Work the center conductor through the hole. (e) Breakout complete; center conductor is completely withdrawn.

3. Mounting and Soldering Components

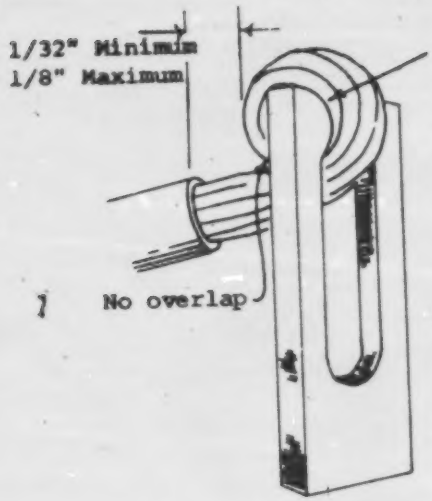
For good mechanical support all wires should wrap around terminals. The standard practice is to wrap a lead around a terminal at least three-fourths of a turn, but not in excess of one complete turn.



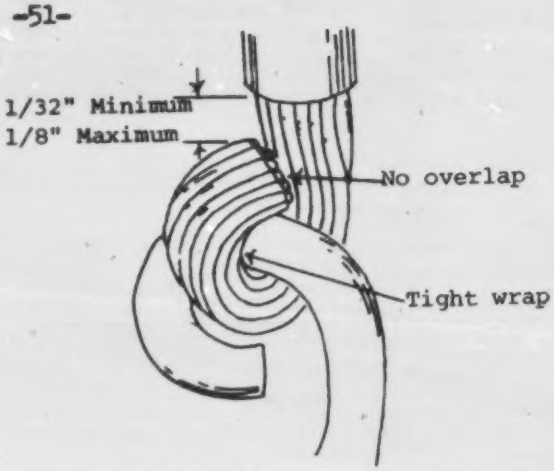
Requirements for mounting tubular components on terminal boards.



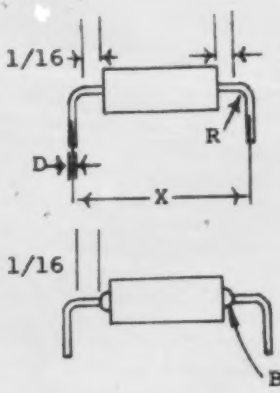
Specifications for wrapping wire around turret terminals.



Wrapping a wire on a flat terminal when approached from a side.



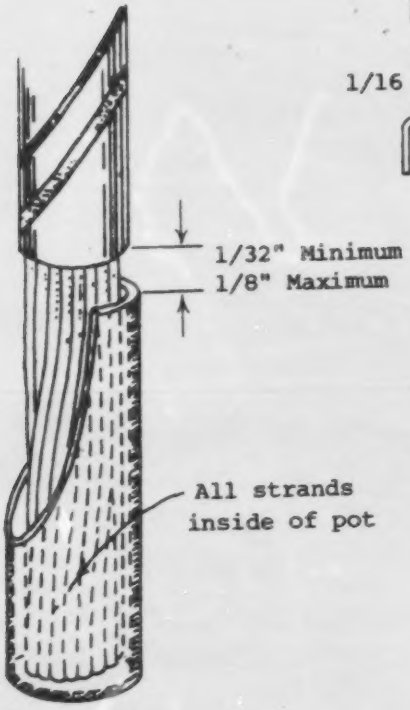
Wrapping a wire around a hook terminal



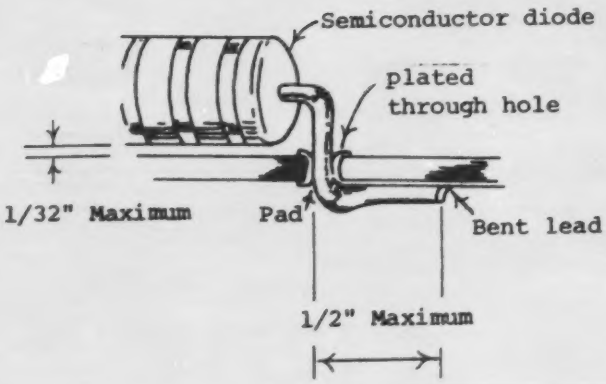
R = 2 x LEAD DIA.

X = 1/16 + 1/16 + 2(R) + D + COMPONENT BODY LENGTH

Bending and Mounting Components on a Printed Circuit Board.



Mounting a stranded wire in solder pot type terminal.



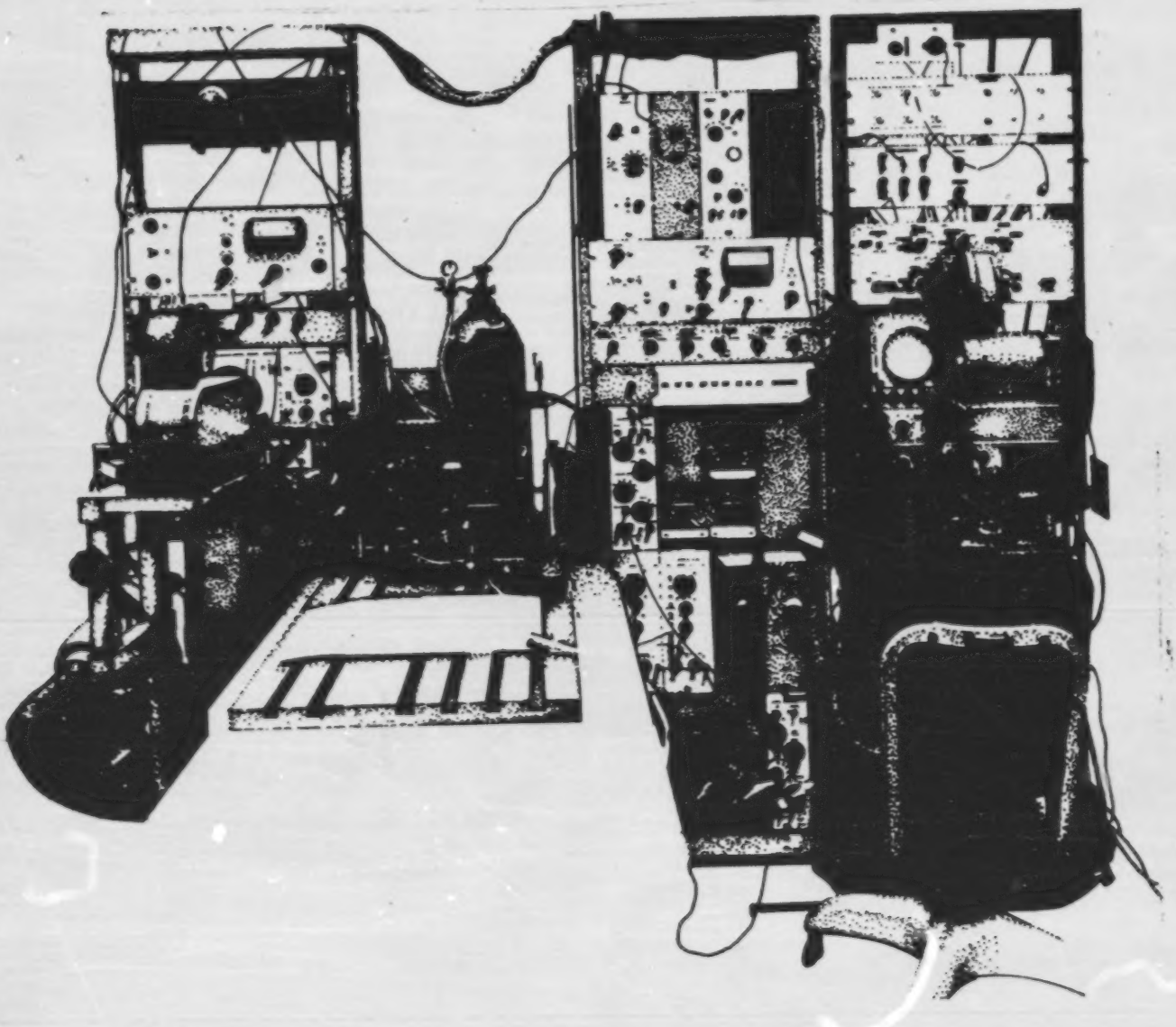
LABORATORY

The student should have enough practice with soldering techniques to answer the following:

1. What will happen if a coarse sandpaper is used when removing enamel insulation?
2. What happens to the current when the diameter of a wire conductor is reduced?
3. What will happen to the electric current if a strand of a wire in a conductor is broken?
4. Why is torn insulation objectionable?
5. Why is it important to know how to remove solder from a soldered joint?
6. State the advantages of using resin-core solder for soldering.
7. Why must the tip of the soldering iron be placed under the soldered joint when removing solder?
8. Why must the soldering iron tip be in a tinned condition when unsoldering a joint?
9. List the advantages and disadvantages of a soldering aid.
10. Explain the procedure involved in removing solder with a copper braid.
11. Why is it acceptable to cut a resistor in half when replacing it?
12. Describe a printed-circuit board.
13. List the specifications to be observed when mounting a resistor on a printed-circuit board.
14. List the advantages and disadvantages of a printed-circuit board.

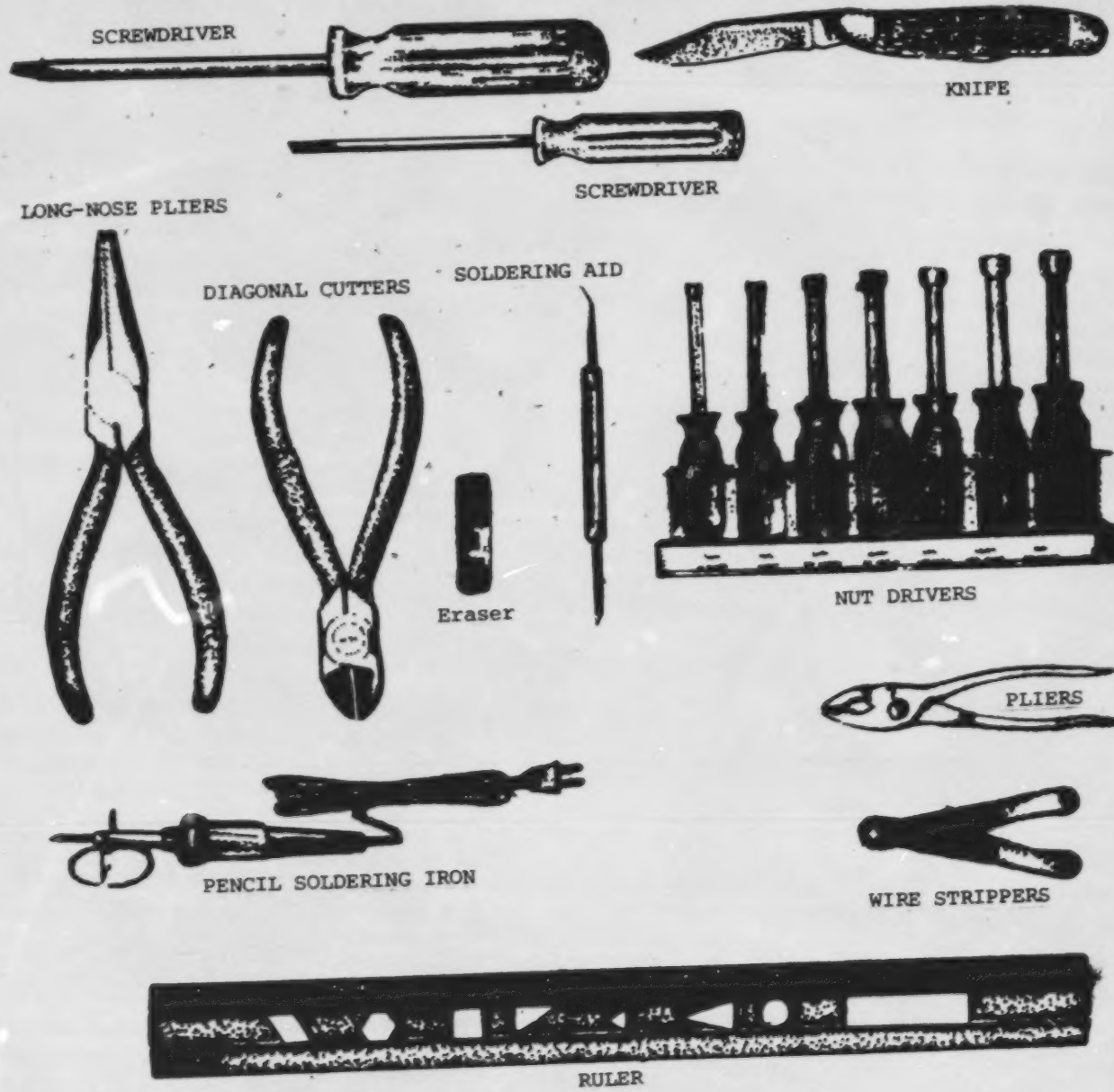
P. Assembly Techniques

The use of integrated circuits (IC's) and digital circuits is rapidly changing the techniques for assemblying electronic equipment. The maze of wiring and panels of circuits shown in the figure below are going to give away to a maze of wiring and the small integrated circuit packages all neatly arranged on a small plug-in circuit board.

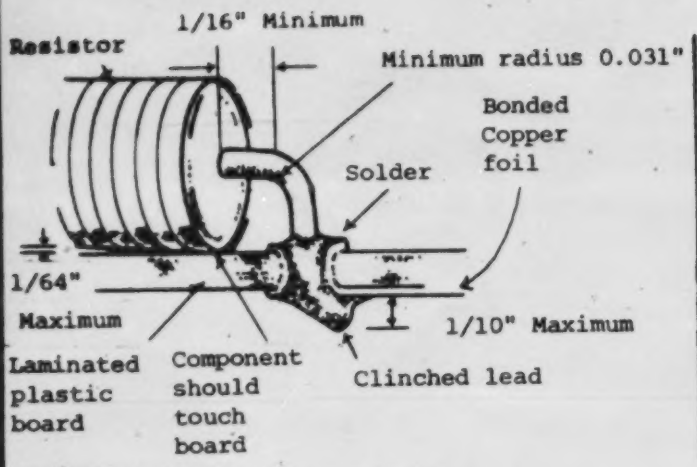


R. Tools

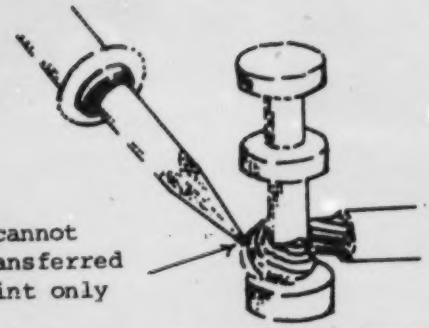
While there exists a large variety of specialized tools an electronic technician needs, the following basic hand tools will be most useful in building or repairing electronic equipment. With the exception of the soldering aid, most of these tools should be quite familiar.



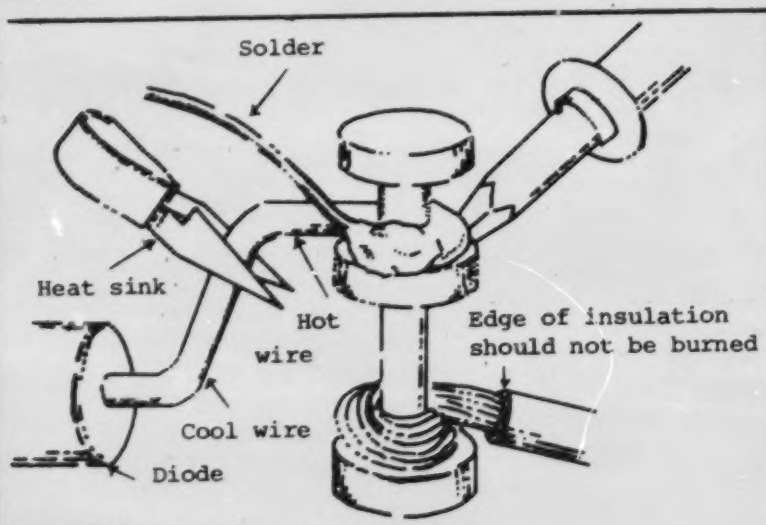
The value and use of most of these tools will become obvious even for the beginner when attempting to work on electronic equipment. Omitted from the basic tools shown is a phillips or cross-point screwdriver.



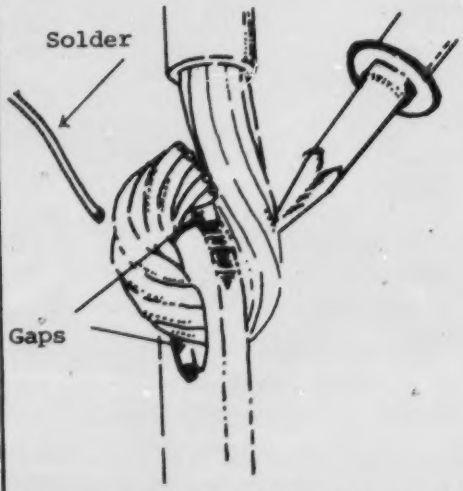
Mounting Components on Printed Circuit Boards. Note shape of solder.



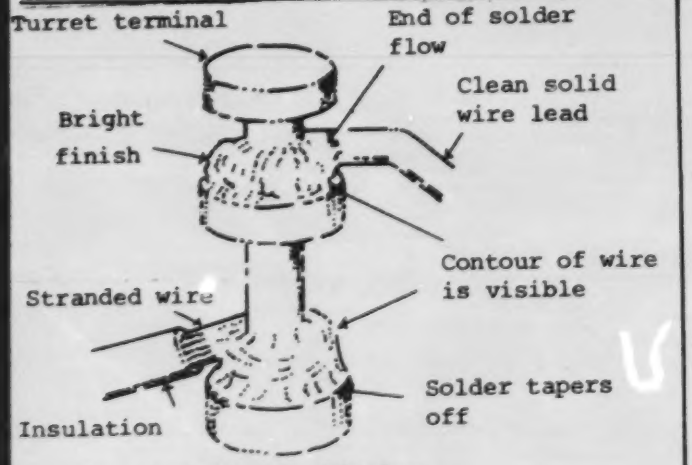
Improper application of heat.



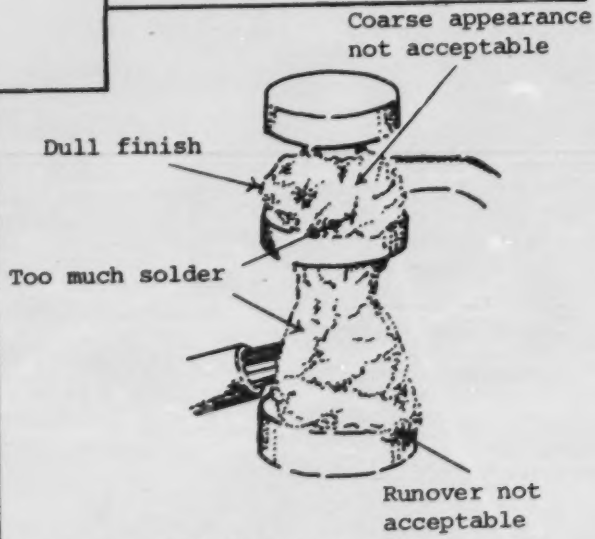
Using a heat sink to avoid damage to components while soldering.



Solder should not be used to fill gaps.



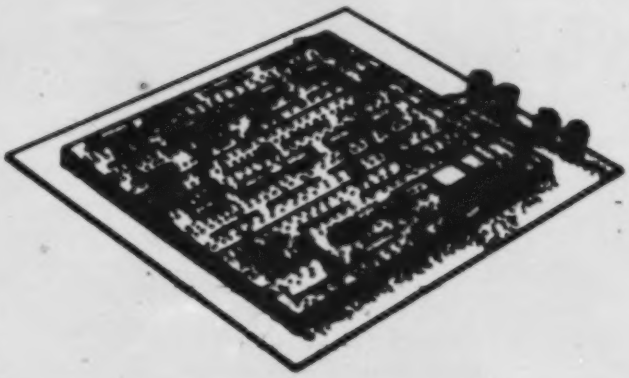
Proper Contour soldering.



Improper soldering results.

The large, involved circuits of the recent past are being replaced by the breadboard and production IC circuit boards shown below.

A breadboard is a plastic sheet of insulation with copper conductors and components mounted through holes in the board. The plastic is reinforced with glass fibers or cloth.



Plug-in IC Breadboard

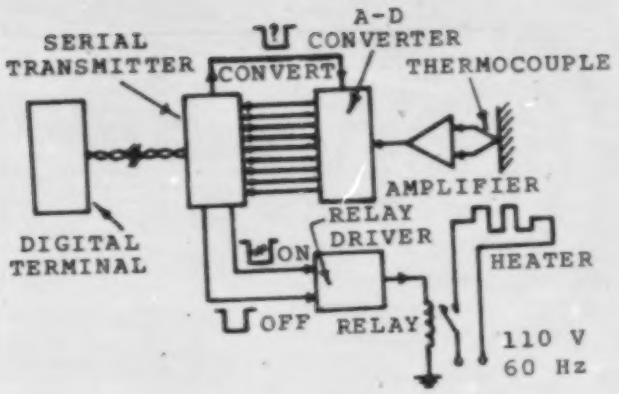
Production IC Circuit Boards

1. Integrated Circuit Assemblies:

The great reduction in space resulting from the use of IC's makes the interconnection problem more complex because of the numerous, closely spaced connection leads that must mate with the "flat packs" or "DIP" IC packages.

Interconnection or wiring drawings and schematics take new form - generally with less information as to the complex circuit that may be inside the IC.

The diagram shown at the right is a remotely monitored and controlled heating process with four IC's (to the right of the Digital Terminal). The only discrete circuit elements are the heater, relay and thermocouple.



Circuit diagram for an automatic/manual heater control.

2. Printed Circuit Assemblies.

Printed circuit boards are usually production assemblies, however, the simplicity with which they can be made make their use valuable even for prototype work. A printed circuit board (PCB) is a plastic laminated board of glass-epoxy, bakelite, or phenolic resin upon which ribbons of copper foil have been etched or conductive paint printed to form conductors interconnecting various electronic components. To etch a copper clad PCB, the following steps are taken.

a. Clean the Copper Clad Board with Ammonia Persulfate 209 and air dry.

b. Apply Kodak KPR4 Photo-Resist in subdued or yellow light.

c. Bake the Photo-Resist Dry in an oven for approximately 150 seconds at a temperature not to exceed 260°C.

d. Expose the prepared board in a photo-printer (ultraviolet source) through a photo negative mask of the desired circuit.

e. Develop the photo-resist in Tri-Chloro-Ethylene (trade name Triad).

f. Rinse off the unpolymerized residue with running water.

g. Dry gently with forced air.

h. Etch the unwanted copper by immersing in a solution of ferric chloride. A Pyrex dish may be used. The solution should be heated and the tray agitated gently.

i. Cut or trim the board to size, drill holes for mounting the components, then strip the polymerized Photo-Resist from the copper surface of the remaining conductors.

j. Finally, mount the components and solder to the PCB connectors.

Preparing the photo-negative has been simplified through the use of adhesive aids. As shown in the figure below, one simply lays out the desired circuit making space only for the size of the components. This master art work then should be photographed to obtain the photo-negative mask.

Laying out master art work with precut adhesive drafting aids.

3. PCB Component Mounting & Soldering

Generally, components are flush mounted to the PCB. Component leads are bent and formed as outlined earlier under Mounting and Soldering Components. The following figures will also help in assemblying components on PCB's.

CORRECT

WRONG

STRAIGHT THROUGH - leads run through board without bending or crimping and are cut to length. A fixture of some kind is usually necessary to hold component in place during soldering.

SPACER - the same as "Straight Through," except that a standoff or spacer is used to keep the component parallel to the board and to provide insulation.

OFFSET - used when the spacing of the leads on a component is too close to accommodate the desired terminal area, or to allow adequate room for conductors to pass between terminal areas. Leads must be formed to fit.

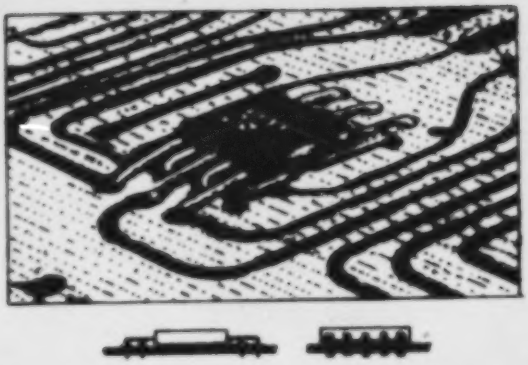
SPREADER - accomplishes the same purpose as the "Offset" configuration, while providing support and insulation.

INVERTED - component is fastened to the board, eliminating the need for a holding fixture during soldering. This method provides support for the component and reduces strain on the leads.

CLIP OR HEAT SINK - combines the advantages of component support with heat dissipation. Terminal area locations are restricted only by lead length and spacing requirements.

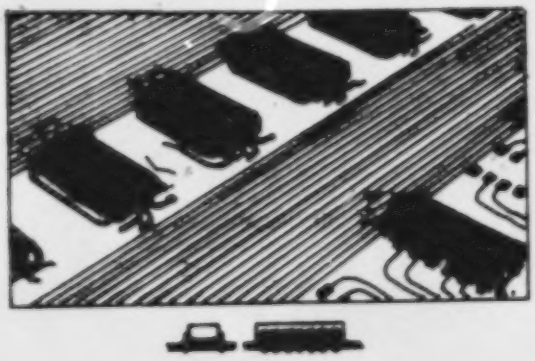
FLAT PACKS

SURFACE - leads are formed and trimmed to size. A holding fixture is usually necessary while leads are soldered.

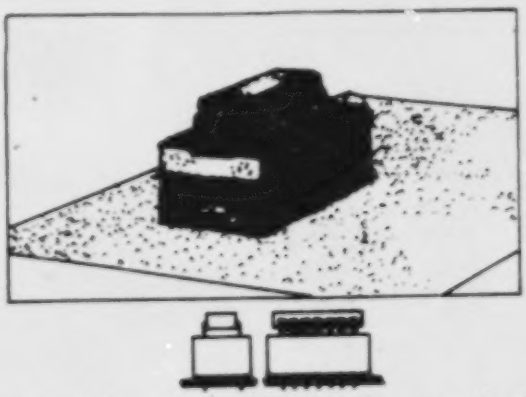


STAGGERED - leads are formed in a staggered pattern and inserted in the board. This method provides clearance between terminal areas to allow for conductor paths.

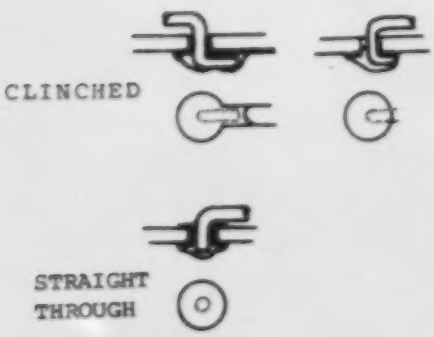
DUAL IN-LINE PACKAGES



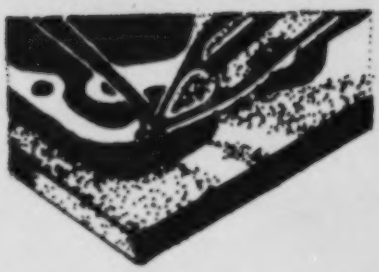
STANDARD - leads are usually flat, but terminal areas are selected by calculating the lead as if it were a (.508mm) diameter wire.



"PLUG-IN" - receptacle is mounted on printed circuit board and soldered. The component is then plugged into the receptacle. Useful where IC's may be interchanged or replaced often.



Component leads may be bent over or "clinched" or simply placed straight into the drilled hole in the PCB. Note outline of contour solder connections.



1. Place the tip of the soldering iron firmly against the circuit board foil and the wire or lug to be soldered.

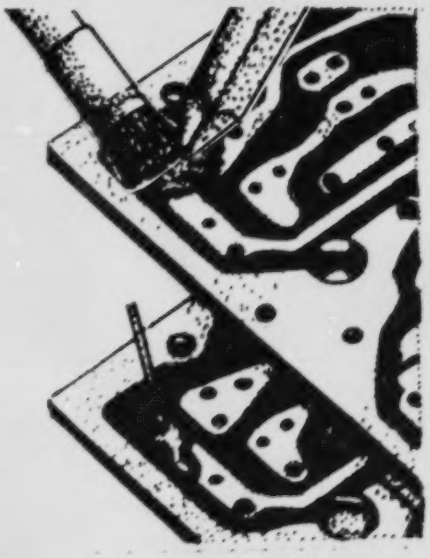
2. Touch the solder to the iron, the foil, and the wire at the point where they meet. Remove the solder as soon as it begins to melt and flow; then remove the iron quickly.

3. Check the connection; a good solder joint should look smooth and bright, and the solder should adhere evenly to both the wire and the circuit board foil.

4. After the solder has hardened, clip off the wire close to the circuit board foil.

If solder is accidentally bridged between two foils, it can be cleaned off by heating the connection carefully, and quickly wiping or brushing away the excess solder with a soft cloth or brush.

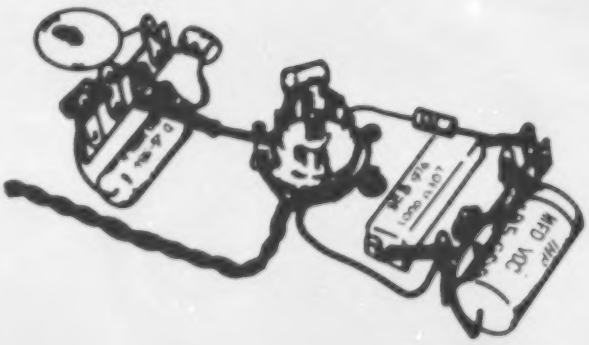
Plugged holes may be cleared by heating the solder over the hole while gently pushing the lead of a resistor through the hole from the other side; withdraw the lead before the solder rehardens.



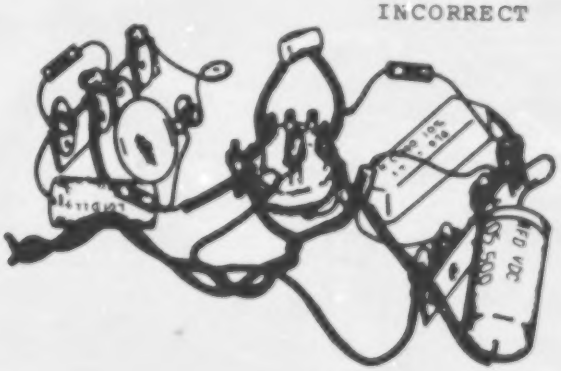
4. Component Layout and Assembly

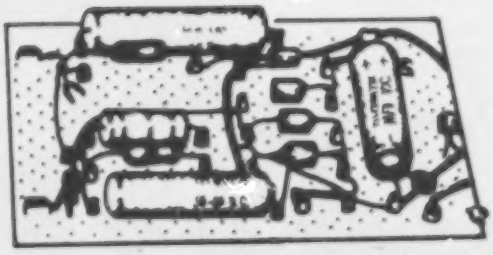
Experience has proven that an orderly layout of components pays in circuit performance. If components are hap-hazard in arrangement, shorts may develop or unwanted "feedback" of signals may occur. The figures below show component layouts.

CORRECT

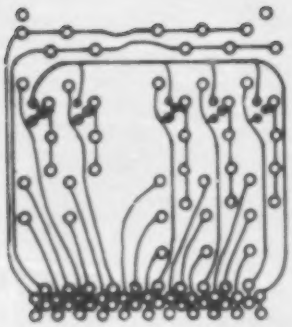


INCORRECT

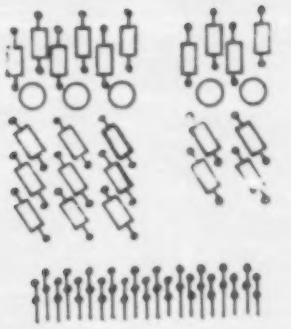




Perf-Board Breadboard



CIRCUIT PATTERN

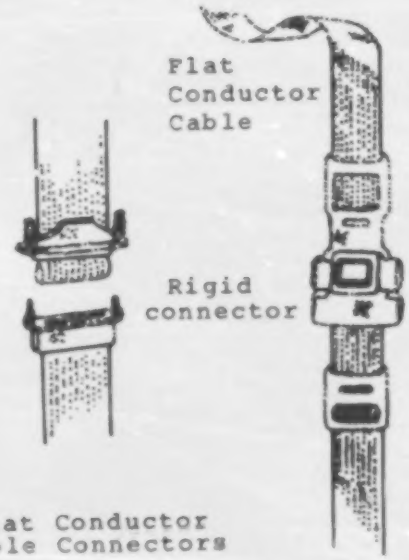


COMPONENT LAYOUT

Printed Circuit Board with component layout on one side and circuit pattern on reverse side.

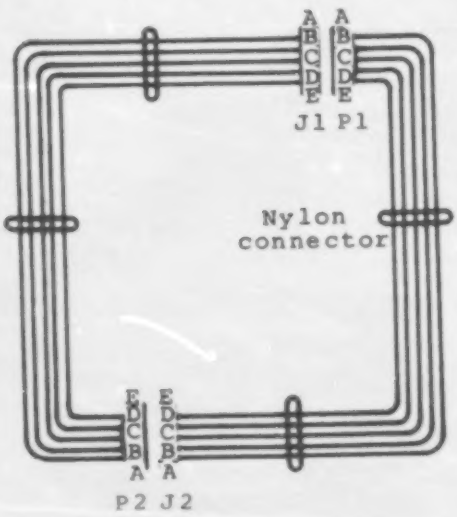
5. Cable and Connector Assembly

While flat conductor cables will not meet every connection requirement, the convenience and wide use makes them worth considering here.



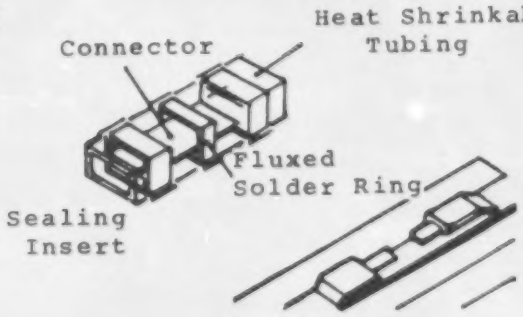
Flat Conductor
Cable Connectors

Cable-Wiring Diagram

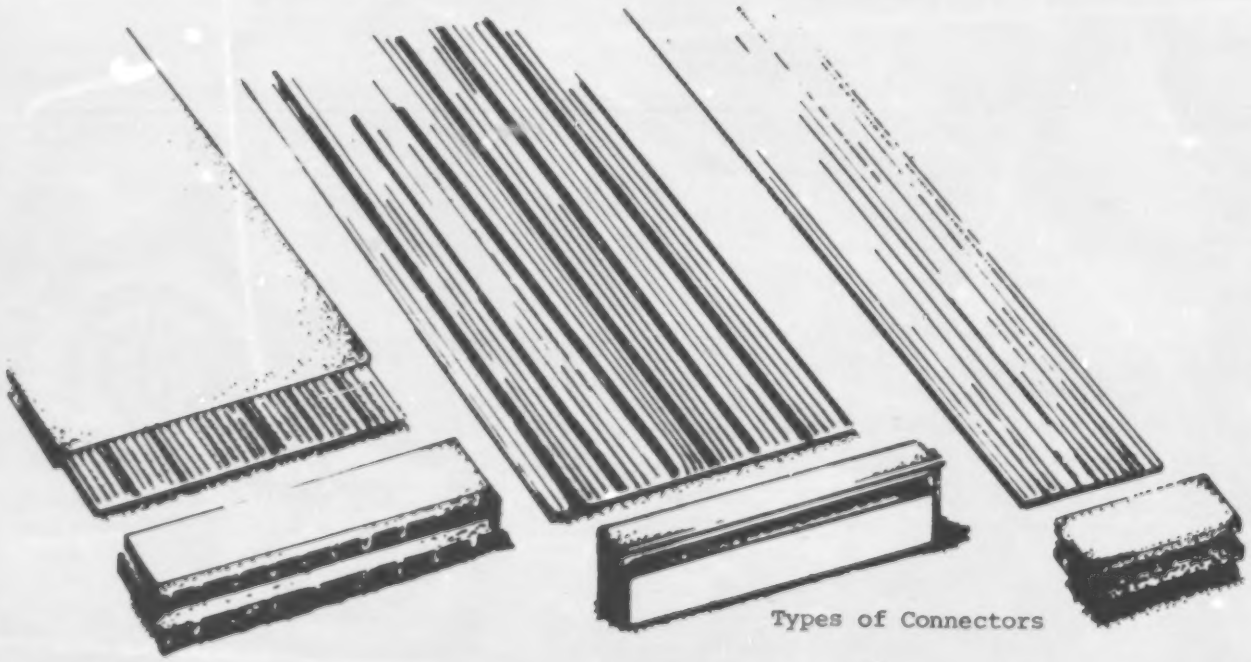


Flat Conductor Cables and Accessories

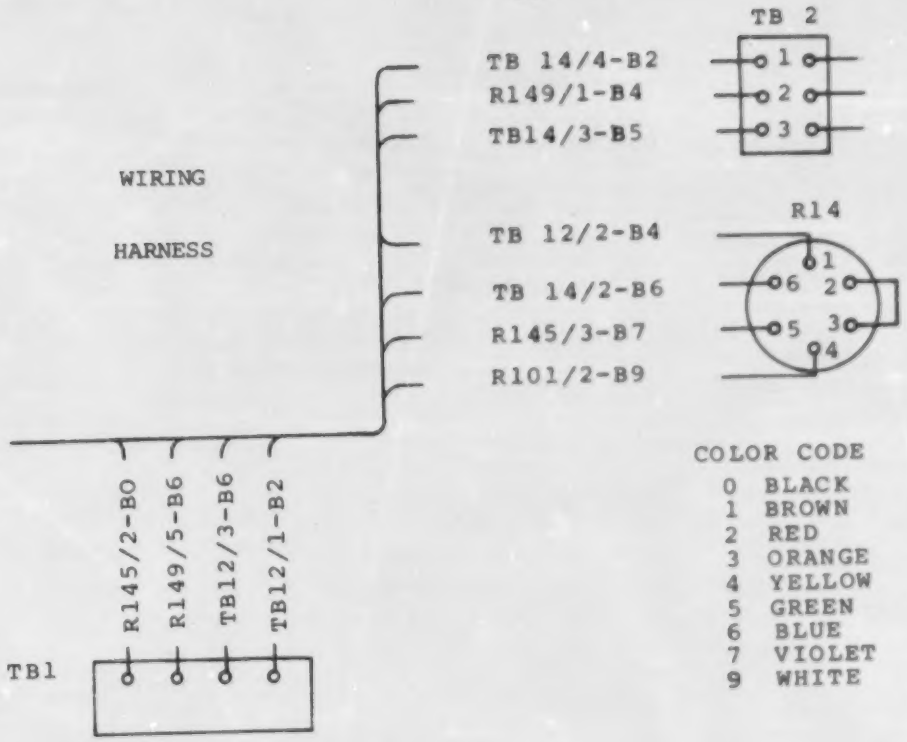
Connector Assembly Tool



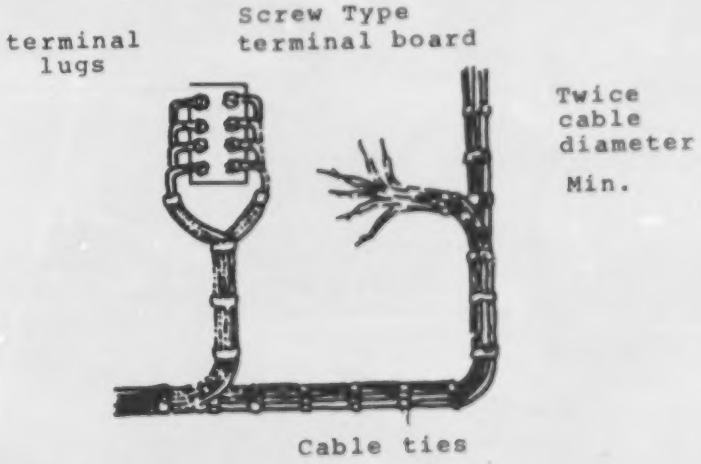
Solder Sleeve Repair Connector



Types of Connectors



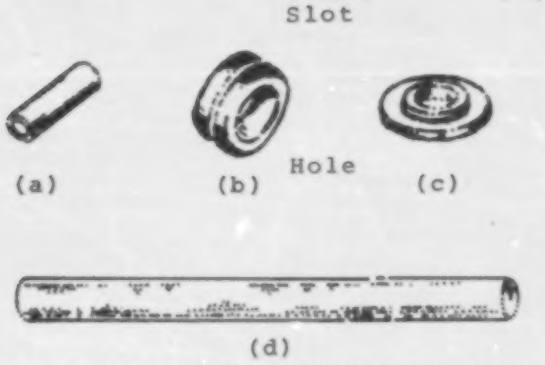
Wiring Harness "Highway Diagram" using American National Identification system.



Nylon Cable ties keep wiring harness orderly

6. Insulating Aids:

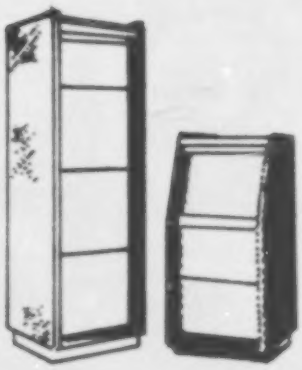
Often it is necessary to mount components without allowing the part to make electrical contact with the chassis. To do this, insulators of different types are available. Four such aids are shown at the right.

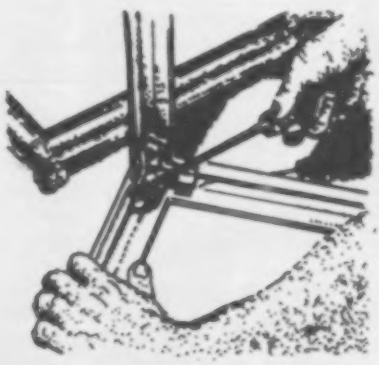


Insulating Aids: (a) Porcelain standoff mounting support (b) Rubber grommet (c) Fiber shoulder washer (d) Plastic sleeving.

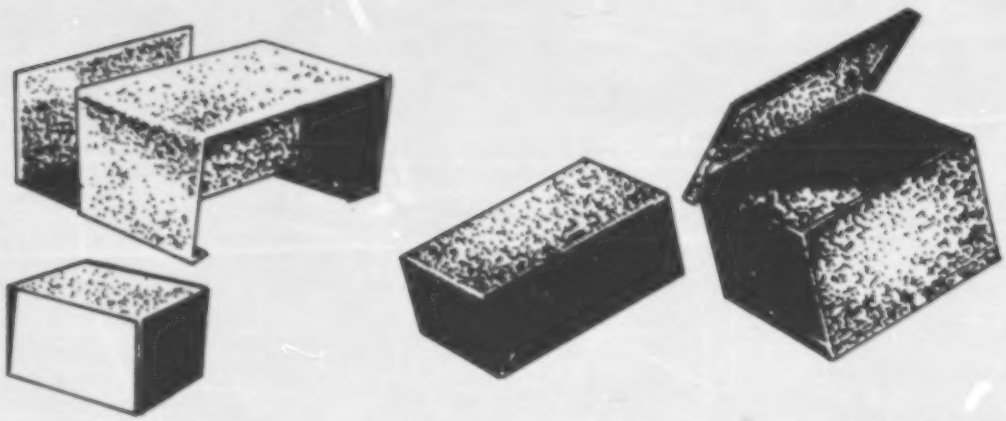
7. Chassis

Generally it is desirable to mount electronic components in a protective box or "chassis" to keep out dust, oil, moisture and avoid shock due to exposed connections. Today it is not necessary to form such a container from sheet metal because several manufacturers make chassis in many sizes and shapes.

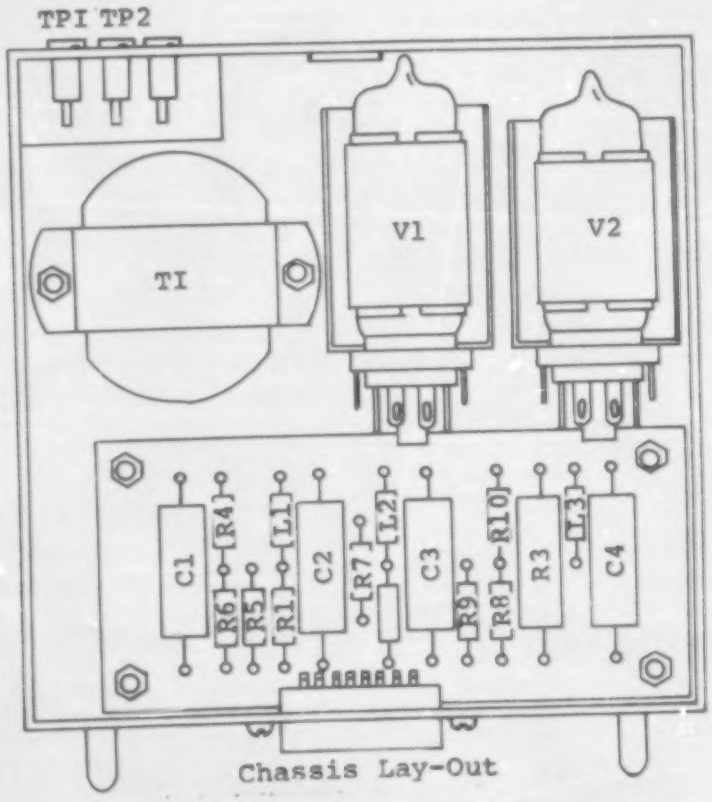




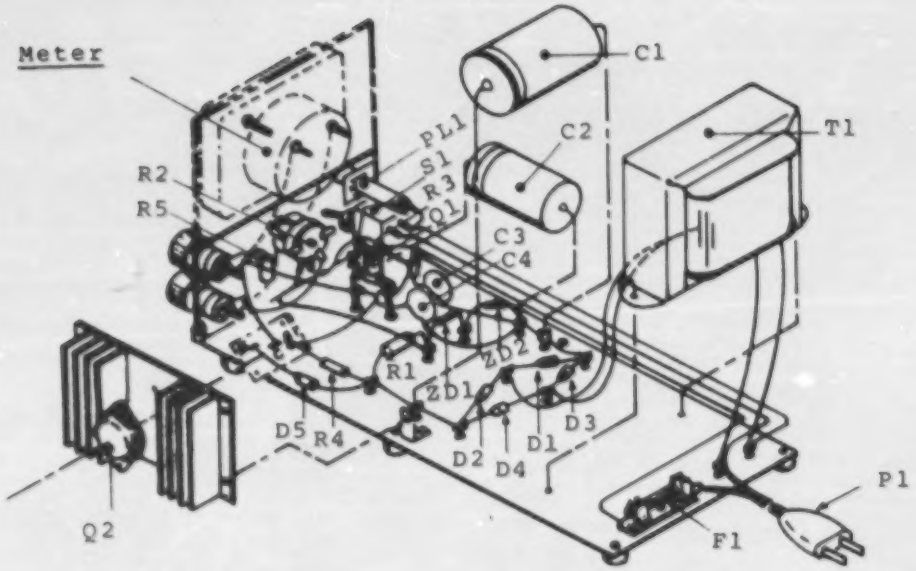
From large cabinets and special assembly techniques to miniature boxes one can now simply select a suitable chassis for packaging electronic hardware.



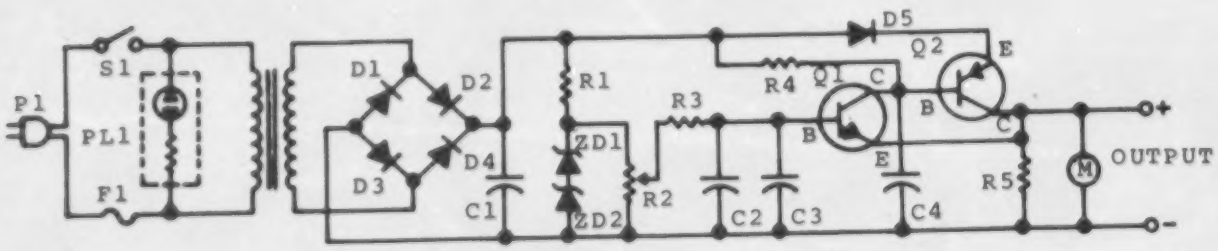
Laying out components in a chassis is generally not restricted to a particular shape, size or terminal location except as required by the application. The figures below are examples of two chassis lay-outs. One has a better organization of components than the other - both are probably good for the application of the equipment.



Chassis Lay-Out



The chassis Layout above (an exploded view) was made from the Power Supply Schematic below.



To make a complete electronic assembly some or all of the following drawings may be required.

a.) Schematic diagram

b.) Component outline drawing (size & shape of components.)

c.) PCB layout and connector pattern.

d.) Assembly drawings of PCB and chassis

e.) Layout drawings of chassis, panel, etc.

f.) Wiring diagram, cable diagram, wiring harness, etc.

g.) Installation drawing

9. Potting Compounds and encapsulating:

The potting and encapsulating of components and electronic assemblies provides protection from moisture, dust and displacement during shock and vibration.

The difference between potting and encapsulating is the method of application. In potting, the component or assembly is completely encased. The potting material in liquid form is then poured into the encased hardware where it soon hardens or cures. In encapsulating, the component or assembly is simply coated in a viscous liquid that also hardens.

Before encapsulating or potting, moisture is removed from components or assemblies by heating or baking in a vacuum.

Examples of various materials used for potting and/or encapsulating electronic hardware include:

a. Epoxy resins

b. Polyurethane resins

c. Silicones (silicone rubbers)

Occasionally these potting and encapsulating materials will have "fillers" added to them to decrease the amount of material required or to improve the thermal conductivity of the compounds.

Electronic components and assemblies are not easily repairable once potted or encapsulated.

Lower density compounds called "foams" can be used to reduce the weight associated with potting components and assemblies while still providing mechanical support and electrical benefits. These foams are made of the same materials mentioned earlier but with an agent that generates a gas in the compounds while curing.

III. HAND TOOLS

Hand tools are small tools, which are hand held and operated.

III-1 HAND TOOL SAFETY REQUIRES PROCEDURES AND EQUIPMENT WHICH MINIMIZE THE CHANCE OF ACCIDENT

Proper procedures and equipment include:

1. Proper tool use.
2. Proper tool adjustment.
3. Proper holding of work.
4. Protect sharp edges.
5. Proper wearer protection.
6. Properly maintained clean and organized work area.
7. Proper safety glasses worn.
8. Proper state of mind, being relaxed and not hurried.
9. Proper cutting tools sharpness.

Proper equipment and uses are described on the following pages.

III.2 LABORATORY

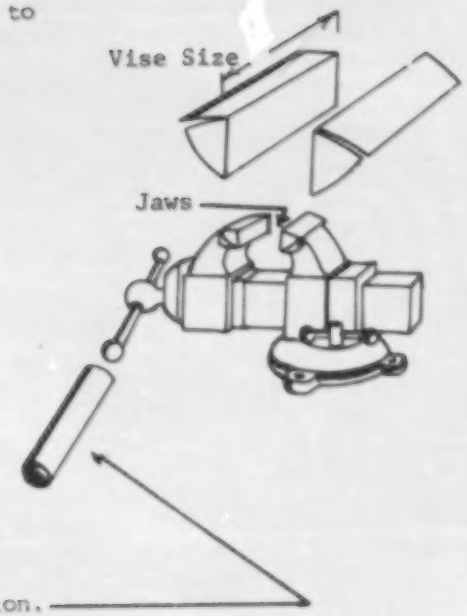
The student should know proper maintenance, application of hand tools, and operator practice to promote safety when using hand tools.

III-2 VISES

Swivel Vise

Do.

1. Use soft brass or copper caps to protect part held.
2. Clamp work tight.
3. Tighten swivel.
4. Bolt down solidly.

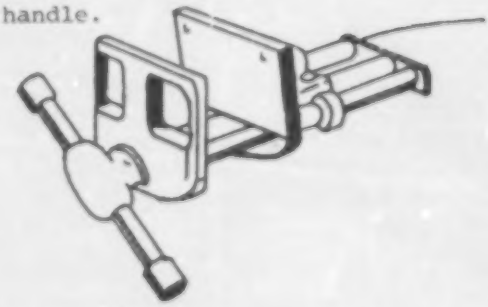


Do Not.

1. Turn handle with pipe extension.
2. Pound handle with hammer.
3. Heat work between vise jaws.
4. Pound on hardened jaws with hammer punch or chisel.

Woodworking Vises

1. Mount vise to sturdy support.
2. Wood faces mount on jaws.
3. Do not over tighten by pounding on handle.



LABORATORY

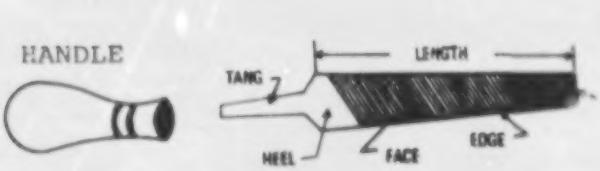
The student should know proper vise use and correct manner to hold work.

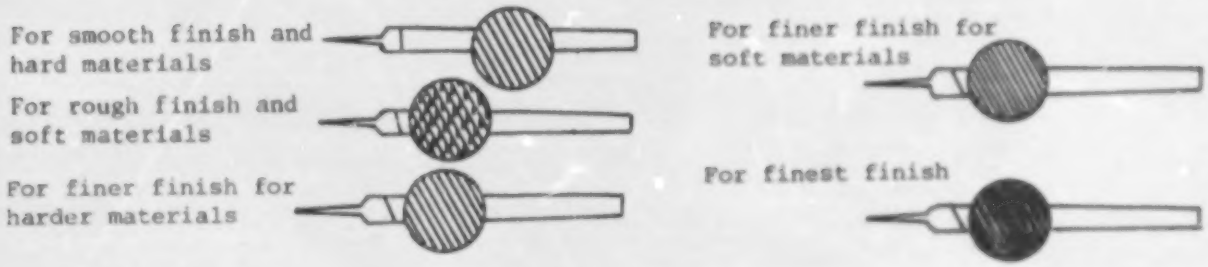
III-3 FILES

A file is a steel tool with a rough, ridged surface for smoothing, grinding or cutting.

Do.

1. Hold file level during stroke.
2. Clamp work securely.
3. Keep file teeth clean with file card.
4. Use handle on tang.
5. Keep cutting teeth free of oil.
6. Keep files separated to prevent dulling of cutting edges.
7. File with long slow strokes. Do not force file.
8. Apply pressure on forward stroke and remove on return stroke.




For smooth finish and hard materials
For rough finish and soft materials
For finer finish for harder materials
For finer finish for soft materials
For finest finish

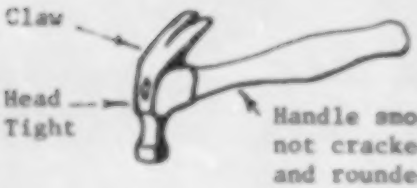
LABORATORY

The student should file plastic, wood, and metal parts using a variety of file types. The student should know file nomenclature and use.

III-4 HAMMERS

A hammer is a tool for pounding, usually with a metal head and a wooden handle.

CLAW HAMMER

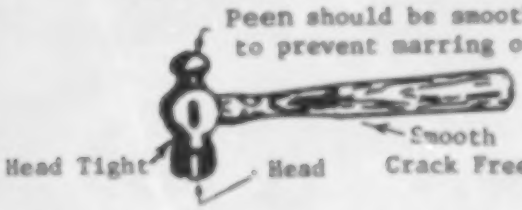


For wood work.

For striking soft steel or iron nails.

Hard Face should be smooth and flat.

BALL PEEN HAMMER

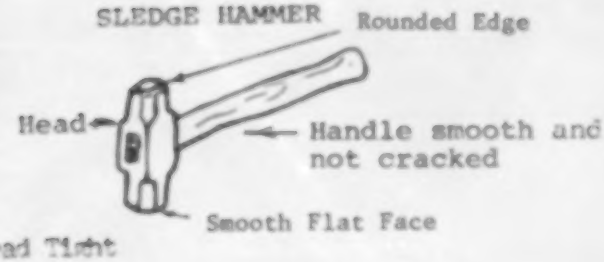


For striking punches or setting rivets. (face)

For forming metal. (peen)

Face should be smooth and flat.

SLEDGE HAMMER



NOTE: Hardened head should not strike hardened material.

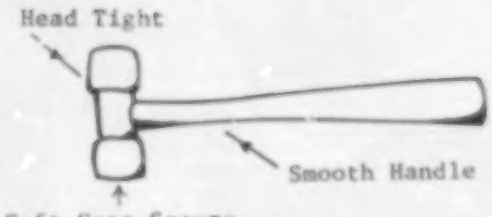
For driving steel wedges.

For driving wood or steel posts.

Hammers should be held at the far end of handle, and one hand at head which moves to rear to finalize stroke.

Safety glasses should be worn.

SOFT FACED HAMMER



Soft face for striking hard objects without marring.

Inspect all hammers for loose heads and broken handles.

LABORATORY

The student should know types and proper use of hammers.

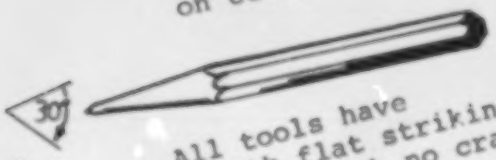
III.5 Punches, Chisels and Impact Tools

All tools kept sharp on cutting edge.

For Metal or Plastic

PRICK PUNCH

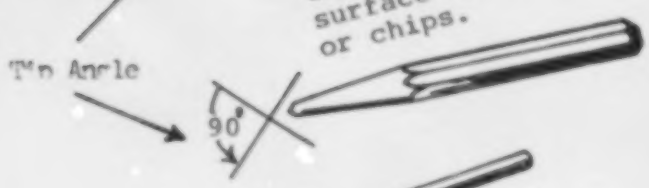
For marking centers.



All tools have smooth flat striking surface with no cracks or chips.

CENTER PUNCH

For making large center punch mark.



For driving out pins.

FLAT CHISEL

For cutting soft metal rivets or sheet metal.

ROUND NOSE CHISEL

For cutting grooves or keyways.

DIAMOND POINT CHISEL

For cutting square corners.

CAPE CHISEL

For cutting grooves or keyways.

For Wood

WOOD CHISEL

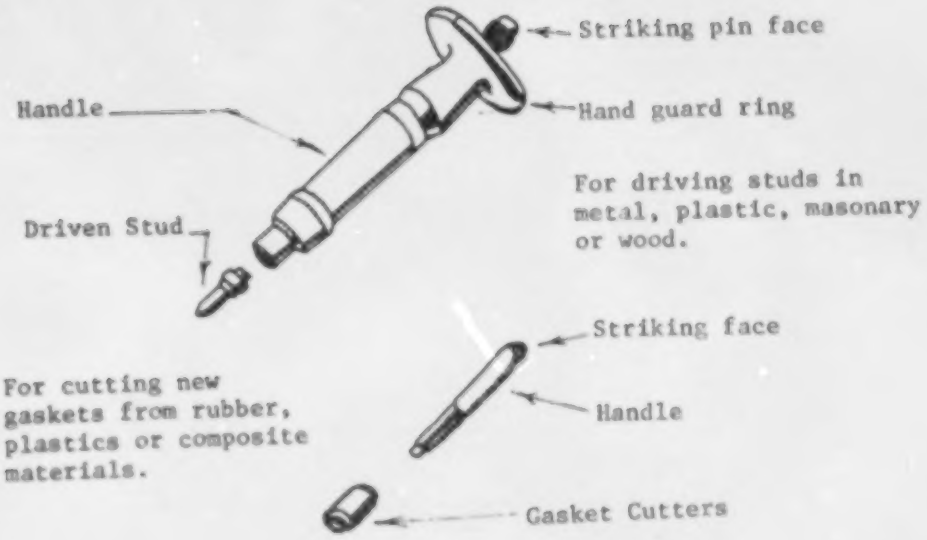
For cutting rectangular recesses in wood for hinges, locks, or openings.

WEDGE

For splitting boards or separating heavy wood pieces.

III.5

Striking face kept smooth and free of cracks.
Driving Tools
Rotation on impact
Hand impact driver for removing corroded or tight epoxy bonded, threaded screws and bolts.



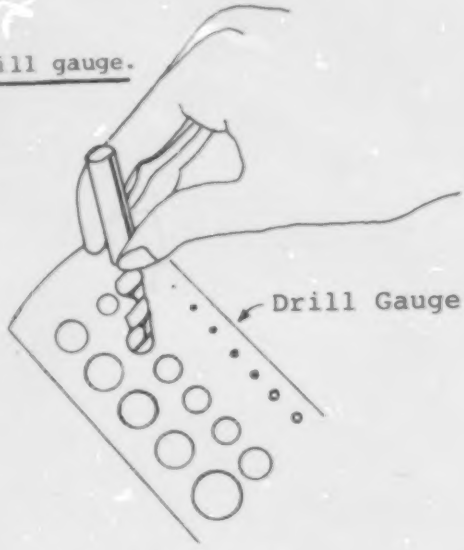
LABORATORY

The student should know uses of punches, chisels, and impact tools in fabrication techniques.

III.6 DRILLS

Drills are used to produce or enlarge holes in or through material. The drills may be hand or electric powered. (Tables of drill sizes are usually posted in the lab.)

A drill size is checked for size using a drill gauge.



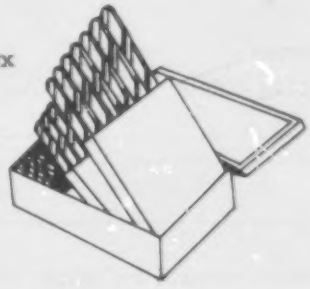
Drill sizes are expressed by the following series.

METRIC - 3mm (0.1181-in, diameter) to 76mm (2.9921-in. diameter)

INCHES AND FRACTIONS 1/64-in.to 3-1/2-in. diameters.

NUMBERS- #80 to #1 (0.0135-in. to 0.2280-in. diameters).

LETTERS - A to Z (0.234-in. to 0.413-in. diameters).



Shank types are:

Straight for Hand drills and small drill presses.

Taper for large drills.

Square tang for wood.

Special drills or bits for metal, plastic, wood, and masonry include:

Hole saw with pilot drill
$\frac{1}{2}$" to 6" size.

Power drill
Wood bits
For $\frac{1}{4}$" to $1\frac{1}{2}$ inches in diameter.

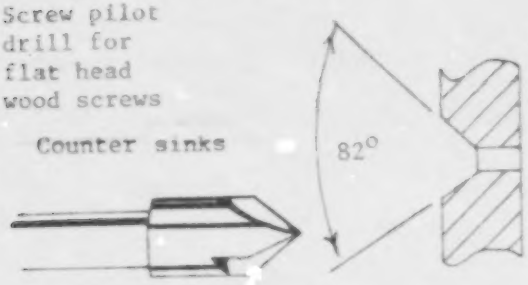
Screw pilot drill for flat head wood screws

Wood Bits for Hand Brace

Standard
$\frac{1}{4}$" up 1".

Expansion type
1" to 3"

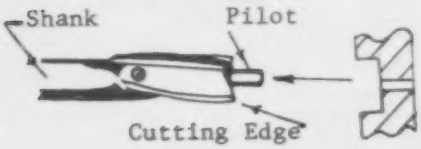
Counter sinks

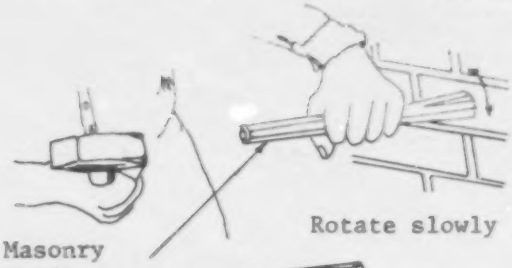


Angles of 60° and 90° are also made.

Power masonry Drill Bit, Carbide Tipped for Brick and Concrete.

Spot face and counter bore





Rotate slowly

Hand Masonry Star Drill

Point of the Star Drill

LABORATORY

The student should be able to identify and use drills for metal, masonry, plastic, and wood. He/she should know the safe use of drills in doing fabrication of parts.

SECTION ITEMS

1. A D size letter drill has a diameter of _____ inches. (.246)

2. A D size letter drill has a diameter of _____ mm. (6.248)

3. A metric drill of 14 mm will drill a hole with a diameter of _____ inches. (0.5512 inches)

4. What number drill size is closest to but smaller than 0.1480 inches? _____ (26)

A drill size chart should be standard equipment in all shops.

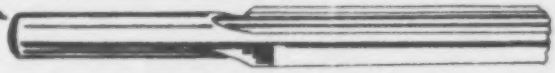
III.7 REAMERS

Reamers are precision ground cutters that remove up to 1/32 of an inch of material from the diameter of a hole to produce a round, straight, smooth hole of specific size. Hand reamers have a square end. A reamer is fed through a hole 1/64" to 1/32" undersize. Turn reamer slowly using cutting oil. After full cut is made withdraw reamer from hole without rotation. Rotation on removal will cut a spiral groove.

Hand Reamers have a square end.

Hand Reamer

Power Reamer



Chucking Reamer

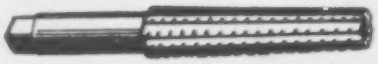
Nuts Move Blades

Adjustable Reamer

Screw Expands Reamer Body

Expansion Reamer

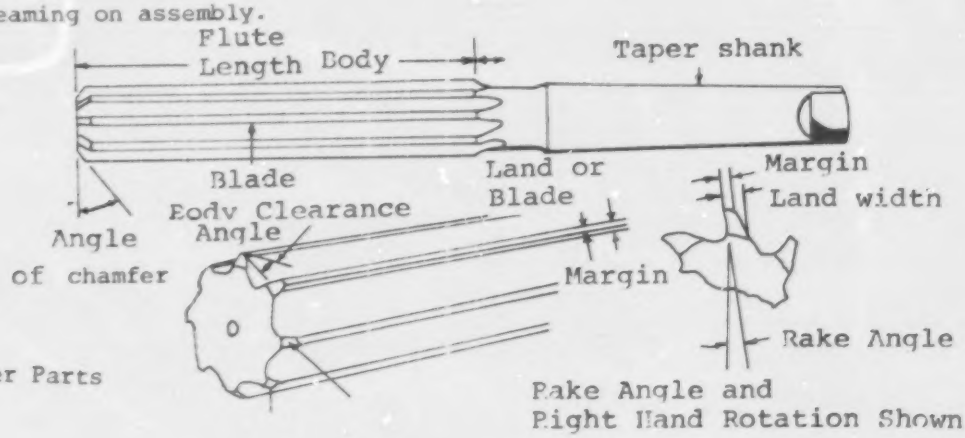
Special Reamers are made to.



Roughing Taper Reamer

- Cut tapered holes for holding taper shank drills and pins.
- Enlarge holes in sheet metal.
- Remove burrs from hole edges.
- Produce precision holes in metal and plastics.
- Match holes in two pieces by reaming on assembly.

Taper Pipe Reamer $\frac{3}{4}$" to foot.



Reamer Parts

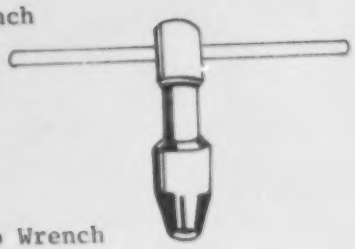
Rake Angle and Right Hand Rotation Shown

LABORATORY

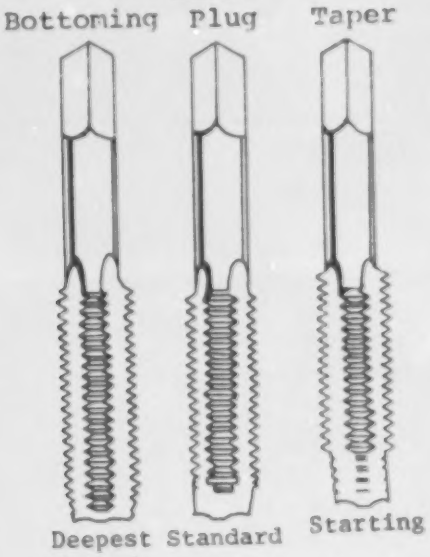
The student should be able to identify and use reamers in lab projects by drilling and reaming holes in metal and plastic. The student should be able to distinguish hand and power reamers. The student should match reaming for dowel pins on assembly of critical parts.

III.8 THREAD CUTTING

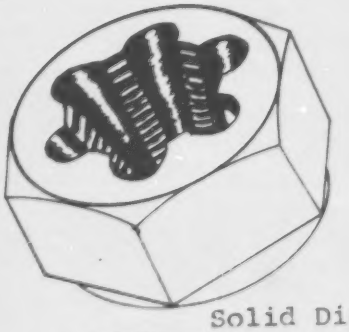
Thread cutting is the process of forming internal threads (tapping) or external threads (using a die). Hand tapping is done with one of three tap shapes depending on the depth of hole and depth of thread in the hole. Oil is used to lubricate the tap and remove chips. The hole size to be drilled called "Tap Drill Size" and the standard thread specifications are available in hand books. Taps are turned with a tee wrench or hand tap wrench. Care must be used to start taps straight in the tap drill size hole. A bottoming tap cuts full threads to the bottom of the hole which is first tapped with a standard tap.

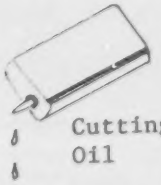

Tee Wrench

Hand Tap Wrench

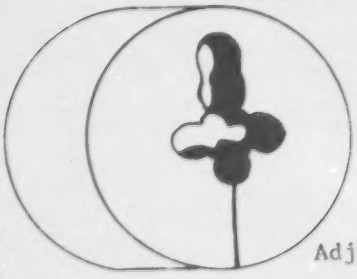


External threads are cut using a die and die stock. Standard thread specifications and rod outside diameters are specified on published thread tables.

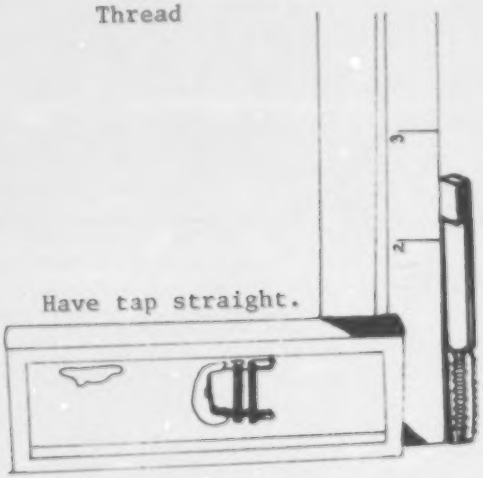

Solid Die

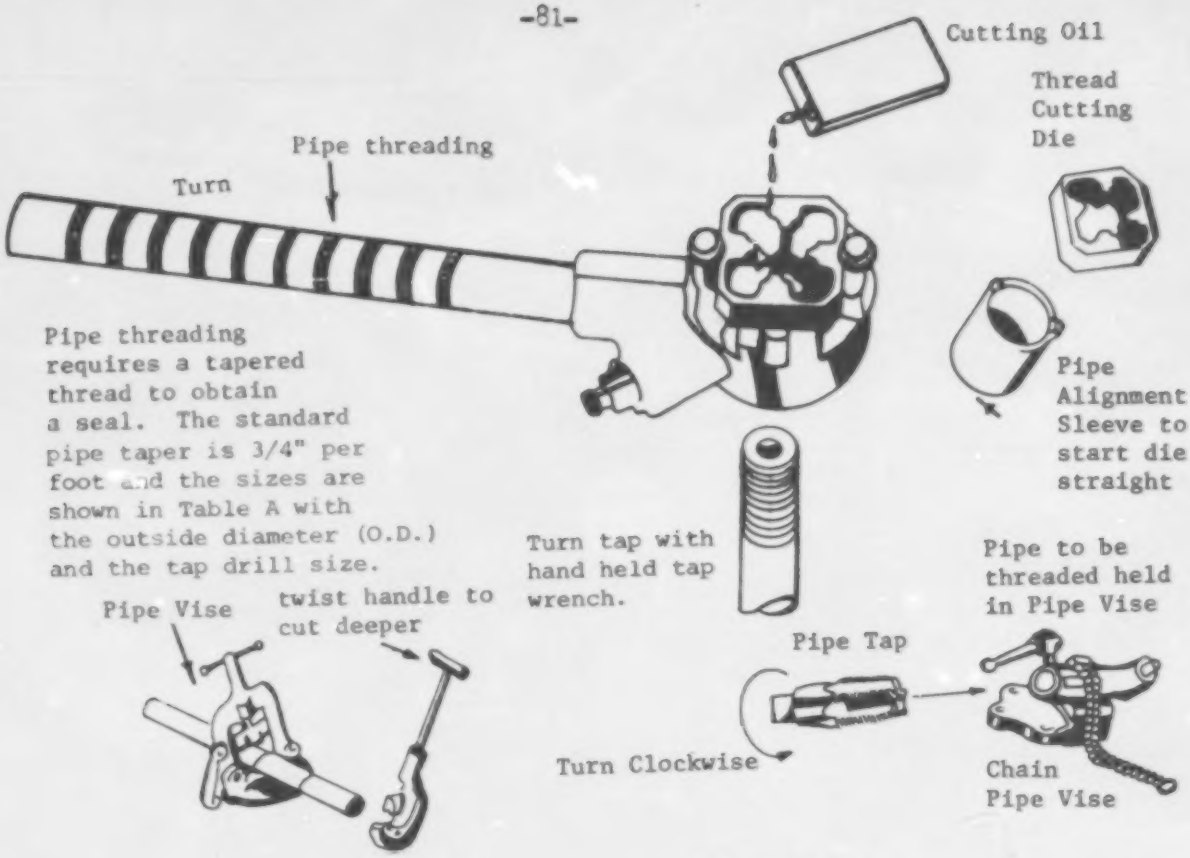


Rod to be threaded


Adjustable Die

Hand Die Stock




Cutting Oil
Thread Cutting Die
Pipe threading
Turn
Pipe threading requires a tapered thread to obtain a seal. The standard pipe taper is 3/4" per foot and the sizes are shown in Table A with the outside diameter (O.D.) and the tap drill size.
Pipe Alignment Sleeve to start die straight
Turn tap with hand held tap wrench.
Pipe to be threaded held in Pipe Vise
Pipe Vise
twist handle to cut deeper
Pipe Tap
Turn Clockwise
Chain Pipe Vise
Rotate to cut

Always lubricate thread cutting taps and dies.

Do not force - clean cut chips often

Pipe is specified by schedule which specifies a standard wire thickness and dimensions.

Schedule 40

Pipe Dimensions

Standard Table A

Dimensions in inches.

Nominal Size	Actual size	Actual Outside	Threads Per Inch	Tap Drill Size
1/8	.270	.450	27	11/32
1/4	.364	.540	18	7/16
3/8	.494	.675	18	19/32
1/2	.623	.840	14	23/32
3/4	.824	1.050	14	15/16
1	1.048	1.315	11 1/2	1 5/32
1 1/4	1.380	1.660	11 1/2	1 1/2
1 1/2	1.610	1.900	11 1/2	1 23/32
2	2.067	2.375	11 1/2	2 3/16
2 1/2	2.468	2.875	8	2 5/8

LABORATORY

The student should understand threading and tapping procedures and should gain familiarity with standard hole and thread sizes using standard threading charts.

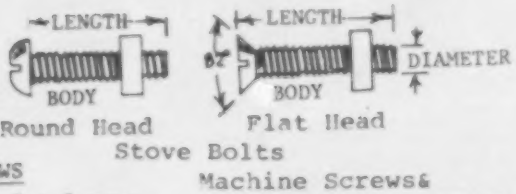
SECTION ITEM

1. A 1/2 inch by 13 threads per inch tap requires what tap drill size?
_____ (0.450)

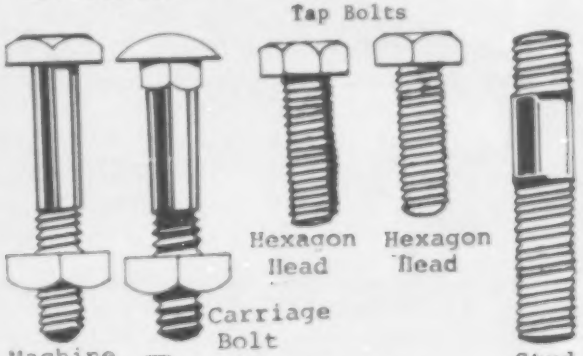
III-9 FASTENERS

Two or more parts may be held together with mechanical fasteners, such as bolts, screws, rivets, retaining rings, dowel pins, keys, and adhesives. Selection is based on application, ease of assembly and cost.

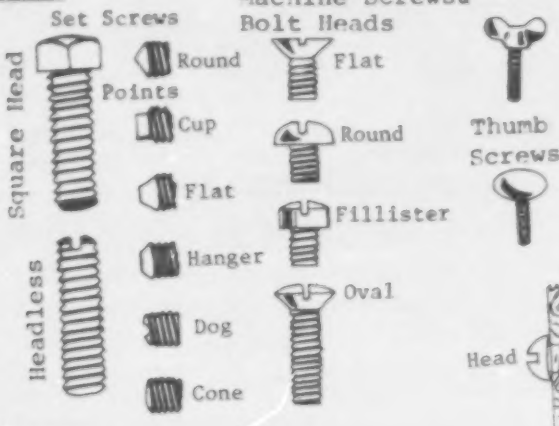
Bolt length equals thickness of material to be fastened plus 1 1/2 thickness of nut.

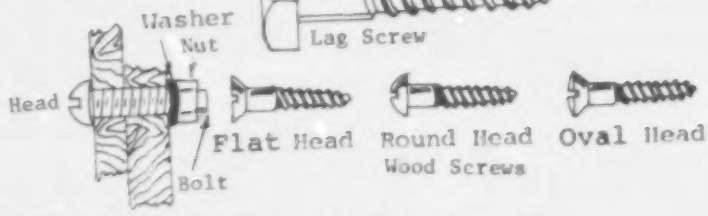


Bolts are used to fasten parts together which may later be taken apart. Use machinery handbook to select head shape, diameter, length, and material.



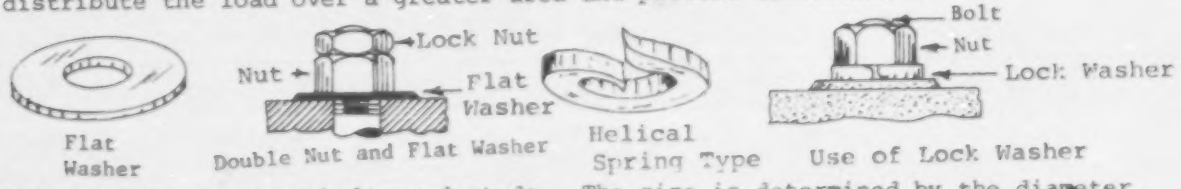
SCREWS



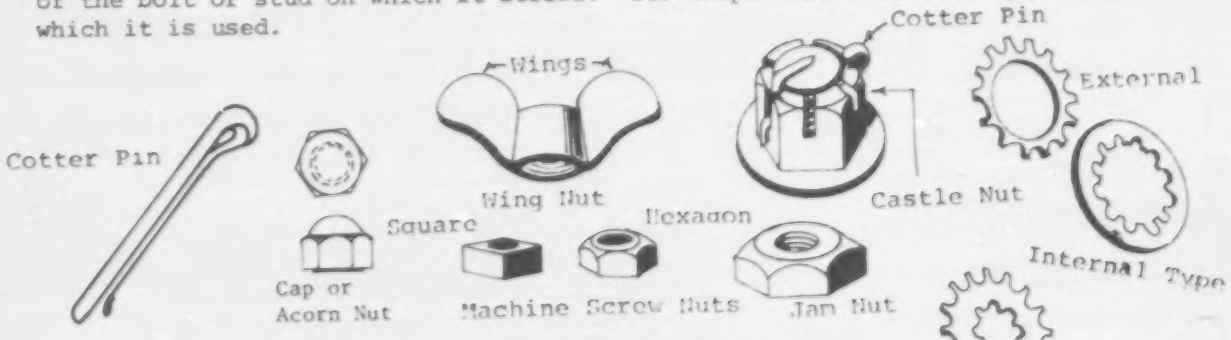


WASHERS

Washers are used as a bearing surface for bolts, screws, and nuts. They distribute the load over a greater area and prevent deformation.



NUTS used to screw on bolts and studs. The size is determined by the diameter of the bolt or stud on which it screws. Its shape will match the bolt with which it is used.

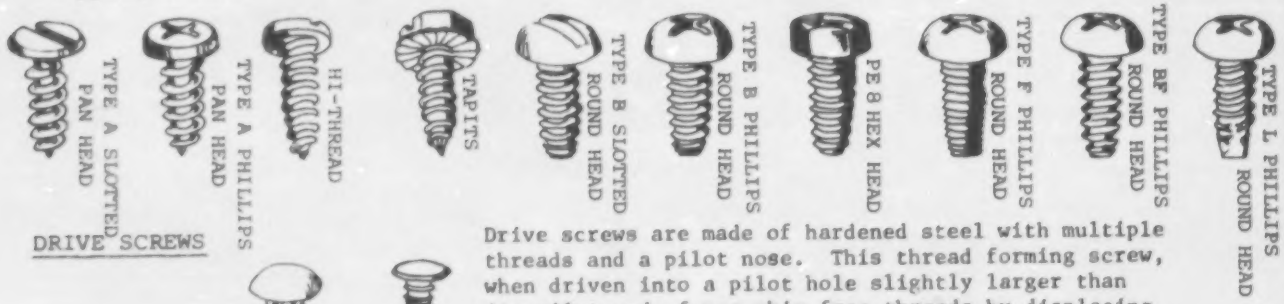


Cotter pins are used to lock castle nut and slotted nuts in place. Jam nuts are thinner than standard nuts and are used to lock a standard nut in place. Cap nuts are for appearance.

III.9

SCREWS

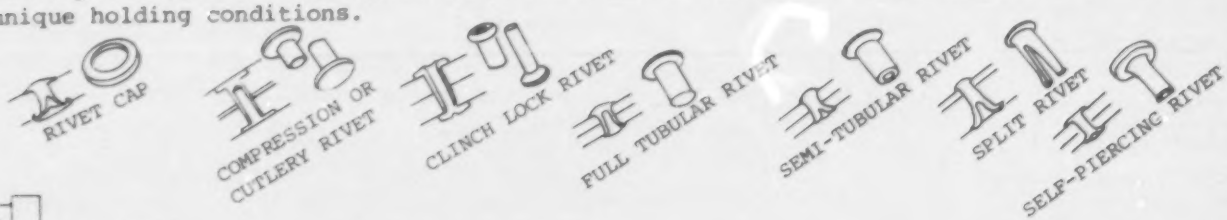
Self tapping and thread forming screws form mating threads by squeezing or displacing material as they twist and cut into holes. They are available in various lengths, head styles, body diameters (according to screw gauge numbers), and are manufactured from many metals. Self tapping screws may be hand or power driven. They are hard, and their use eliminates the need for tapping holes.

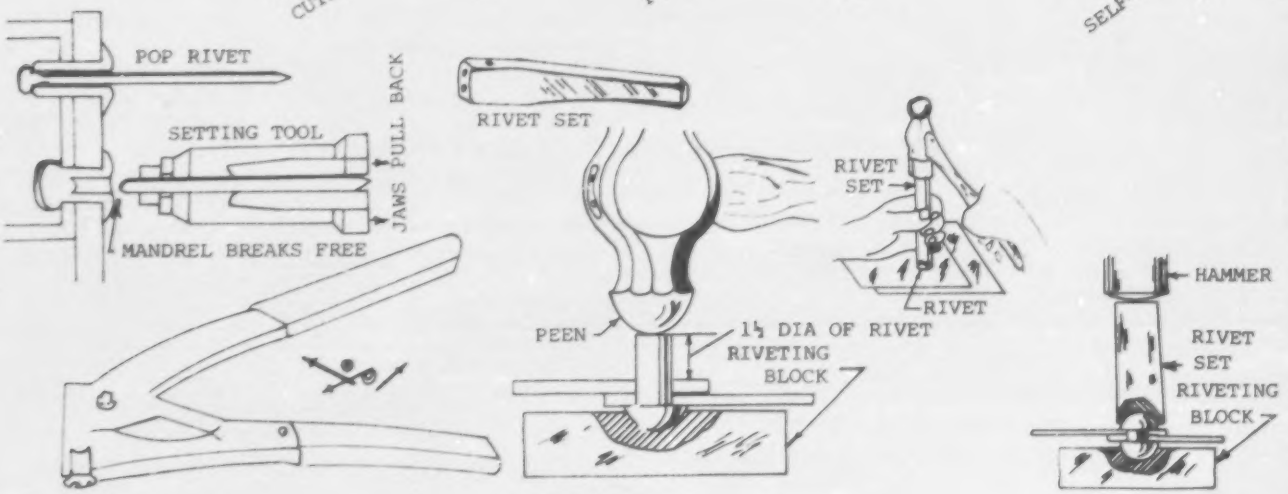

TYPE A SLOTTED PAN HEAD
TYPE A PHILLIPS PAN HEAD
HI-THREAD
TAPITS
TYPE B SLOTTED ROUND HEAD
TYPE B PHILLIPS ROUND HEAD
PE 8 HEX HEAD
TYPE F PHILLIPS ROUND HEAD
TYPE BF PHILLIPS ROUND HEAD
TYPE L PHILLIPS ROUND HEAD

DRIVE SCREWS

Drive screws are made of hardened steel with multiple threads and a pilot nose. This thread forming screw, when driven into a pilot hole slightly larger than its pilot end, forms chip free threads by displacing material within the hole and makes a permanent fastening in metal, plastic, plaster, and other materials.

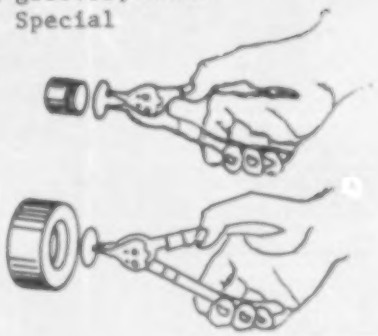
RIVETS are soft metal fastening pins which may be hollow, solid, or split and are used to make permanent assemblies. They are available in various sizes and head shapes, are set by hand or machine while cold or hot. Pop rivets, drive pin rivets and explosive type rivets are examples of special rivets for unique holding conditions.





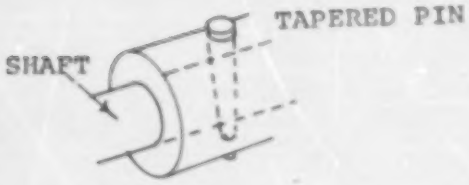
RETAINING RINGS

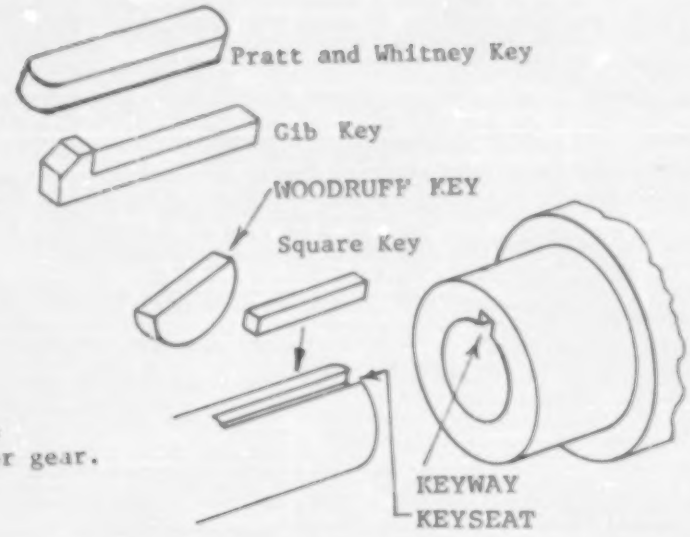
Retaining rings are fastening devices for external and internal applications. Most retaining rings are seated in grooves, while self-locking type rings do not require a recess. Special pliers are used to install and remove the rings.



DOWEL PINS

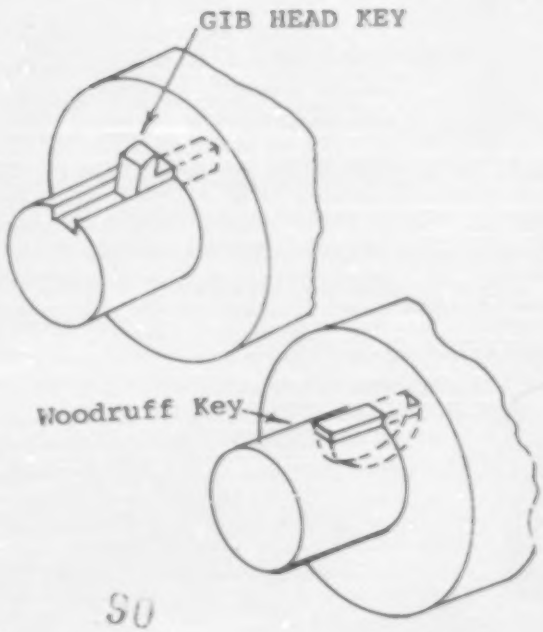
Dowel pins are used to hold two mating parts (gears on shafts) and support a major part of the load placed upon the composite unit. Most pins are tapered and fit into tapered reamed holes of 1/4 inch per foot.





KEYS

Keys are made in several shapes and used to prevent a pulley or gear from rotating on a shaft. One-half of the key fits into a keyway in the shaft while the other half fits into the pulley or gear.



ADHESIVES

One fastening technique utilizes a load bearing bond which contributes to the strength of the structure. This mechanical bonding sometimes yields a point stronger than the materials being joined. Adhesives require a clean surface that mate, and thus, machining, drilling, etc., are eliminated. The surface must be clean and fit properly before applying the adhesive. The adhesive may be sprayed, dipped, brushed or rolled on the mating surfaces before assembly. Some applications require pressure for curing, others cure by evaporation.

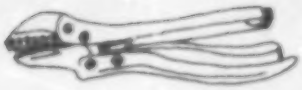
III.10 GRIPPING AND CUTTING TOOLS

Pliers are to be used for gripping, twisting, or cutting. Pliers are designed for many special applications, but should be used on non-machined surfaces since they may mar the surface.

Hand gripping tools and their uses include:

Clamping parts or turning tight studs.

Holding parts to be soldered.
Turning fasteners.
Bending or cutting wire.
Wire cutting, bending and insulation stripping.
Turning wire connectors.



Locking pliers

Combination or slip joint pliers

Linemans pliers

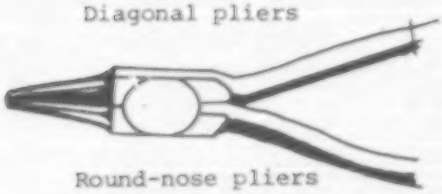
Straight needle-nosed pliers

Holding small parts, cutting and bending fine wire.

Diagonal pliers

Cutting wire close to a surface.

Bending solid wire without nicking surface for electrical eonnections.



Round-nose pliers

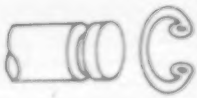
Gripping large diameter tubing, nuts, pipe fittings, or parts. (Normally used for plumbing.)

Curved joint pliers

Cutting nails, wire, and small bolts.

End cutting nippers

Expanding small retainer rings.



Snap ring pliers

Stripping insulation from solid or standard electrical wires of aluminum or copper.

Wire stripper

Cutting steel bolts and wire as large as 1/4" to 3/8".

Wire and bolt cutter

III.11 SCREW DRIVERS

A screw driver is a chisel shaped tool with a blunt end to fit into the slot in the head of a screw.

Screw drivers are designed to install and remove screw fasteners. Screw drivers may have spring clips, magnetic blade or split blade to hold screws for positioning in hard-to-reach places.

Split blade may be damaged by too much torque.

Improper Procedures

Twisting handle with wrench

Prying

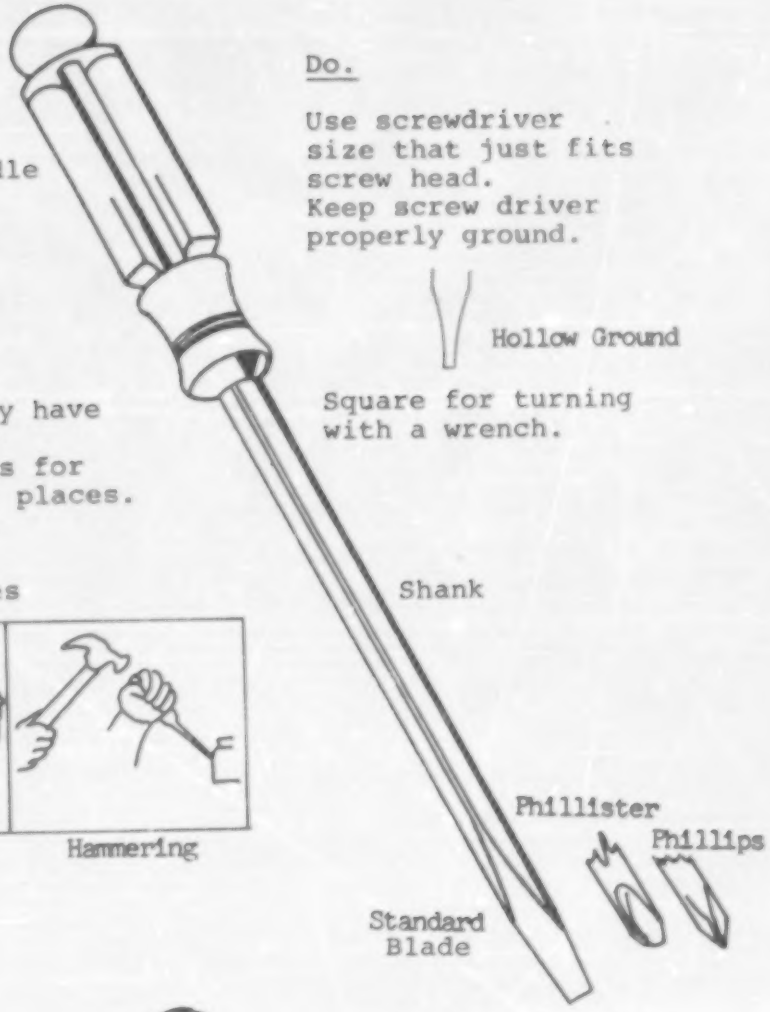
Hammering

Do.

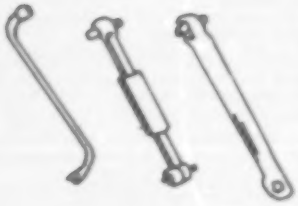
Use screwdriver size that just fits screw head.
Keep screw driver properly ground.

Hollow Ground

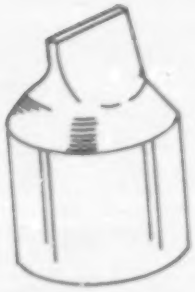
Square for turning with a wrench.



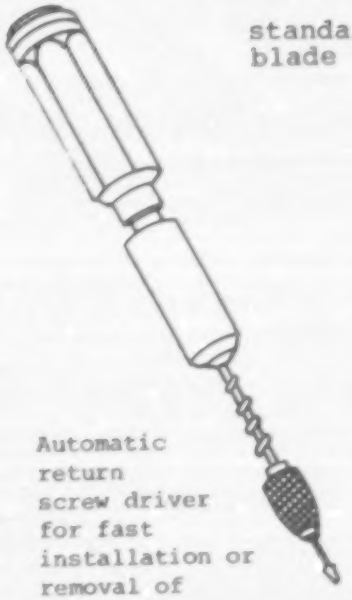
standard screw blade types



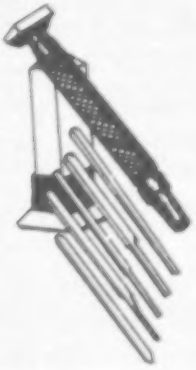
Offset screw drivers for tight places



Screw driver for socket set



Automatic return screw driver for fast installation or removal of screws



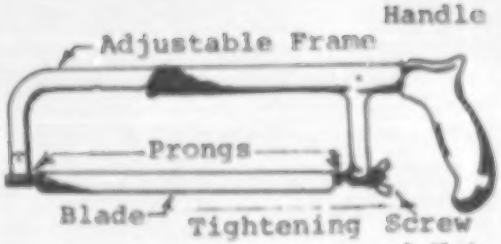
Jewelers screw drivers for small screws

III.12 SAWS

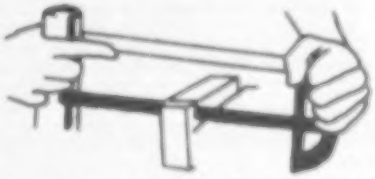
Hand saws are designed to cut metals, plastics, and wood. Hand saw cutting blades are designed to cut with a steady light pressure on the work piece. Maximum cutting speed should be 60 strokes per minute. Faster speeds dull the cutting edges and cause rougher surfaces.

Downward pressure is applied on forward stroke only.

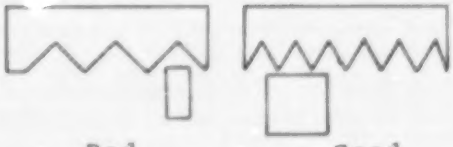
Cutting edges should have fine enough teeth to prevent hooking on the material being cut.



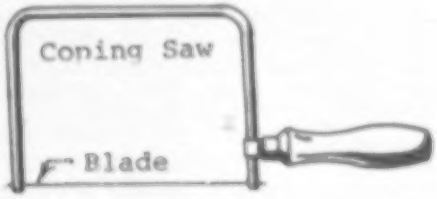
HAND HACKSAW
For cutting metals



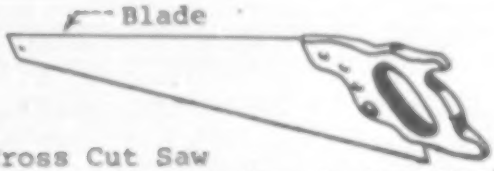
Correct method of holding hacksaw



Teeth Per Inch	Metal Thickness
18	up to ¼"
14	¼" to ½"
10	½" to 2"
8	2" to larger

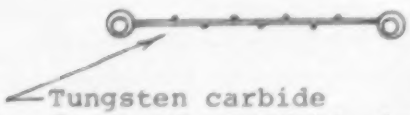


For fine cuts in metals

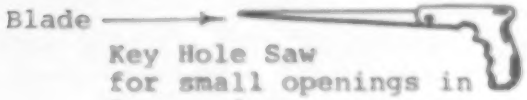


Cross Cut Saw
for cutting lumber to length

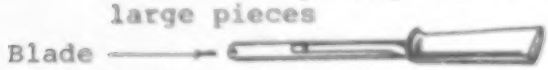
A special blade made from tungsten carbide is used for very hard materials.



Tungsten carbide fastened to small wire



Key Hole Saw
for small openings in large pieces



Hacksaw for holes in large metal or plastic sheets.

III.13 WRENCHES

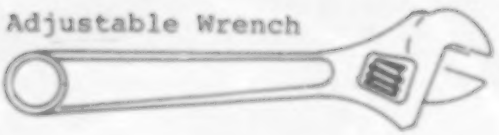
A wrench is a tool used for turning nuts, bolts, pipes, etc.

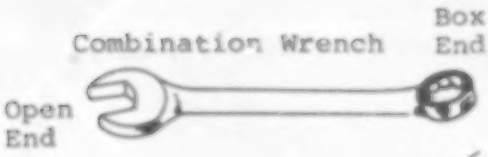
Wrenches are used for turning fasteners or parts by pulling toward the body. Wrenches are in metric sizes (mm), fractional sizes (inches) and whitworth (English).

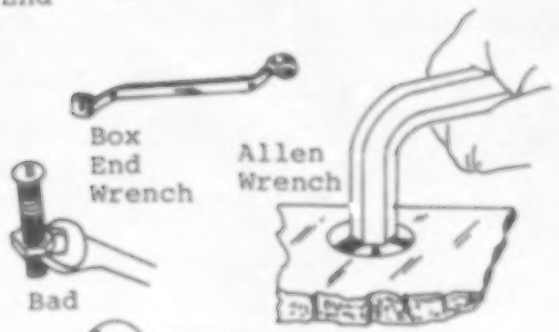
Wrenches should always be kept clean and fully engaged with the item to be turned. Partial engagement causes damage to the wrench and the work piece.

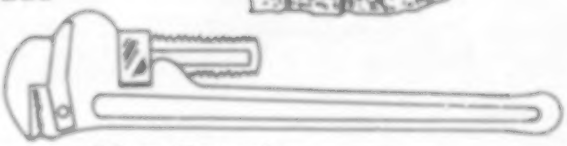
Special wrenches include:

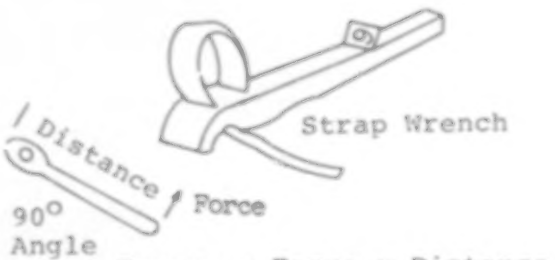
Adjustable wrenches for turning nuts, bolts, tubing couplings of various sizes. Always pull against solid jaw.
Box and open end wrenches of fixed size to turn square or hex head fasteners with great force.
Allen wrenches to turn cap screws or Allen head screws.
Pipe wrenches to tighten pipe or pipe couplings in assembly.
Torque wrenches to measure torque applied to rotate a fastener.
Strap wrenches to hold or turn round or irregular shaped objects.
Spanner wrenches to turn large diameter or hollow parts and fasteners.
Socket wrenches to get in hard to reach areas and speed installation or removal of fasteners such as bolts.



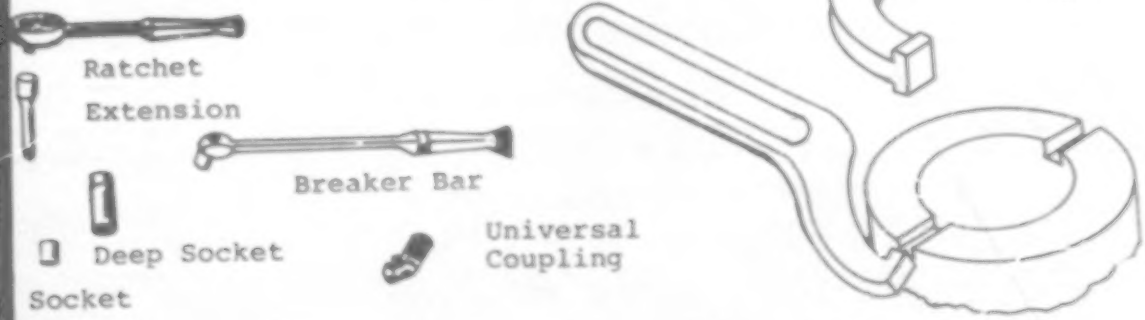








Socket Wrench Set



III.9-13. LABORATORY

The student should be able to choose and identify fasteners and use them in assembly. He/she should be capable of identifying, selecting, and using a number of gripping and cutting tools. The student should develop knowledge of identification, selection and use of screw drivers. He/she should develop knowledge of identification of types of saws and the application of various saws to fabrication work through projects with wood, plastic, and metal. The student should learn the proper use of wrenches while fabricating or servicing an assembly.

III.14 END OF CHAPTER PROBLEMS

WORKED EXAMPLES

1. A 5/16-18 thread is to be tapped in a hole. What tap drill size is required?
   Use thread table and find the thread specified.
   Read to the right and find the tap drill size of F .
   A letter drill of size F would be used.

2. A 1/8 inch pipe is to be threaded into a brass connector. What tap drill size is required?
   Look at table A of Section III.8 "Standard Pipe Dimensions".
   Find nominal pipe size of 1/8 inch. Read to right to tap drill size column. Tap drill is 11/32 inch.

STUDENT PROBLEMS

1. An adjustable wrench ( )does, ( ) does not, mar the head of a bolt which is being turned.

2. A tool box for a lab technician who does assembly, wiring, and piping work might have which of the basic hand tools presented in the chapter.
   (Name 14-15 items)

   _____ _____
   _____ _____
   _____ _____
   _____ _____
   _____ _____
   _____ _____
   _____ _____

   (Linemans pliers or long nose pliers, vise gripping pliers, Phillips screw driver set, standard screw driver set, adjustable wrench or open end wrench, hammer and pin punch, Allen wrench set, file, drill set, pop rivet set, jewelers screw driver set, hacksaw, assortment of fasteners, wire stripper.)

3. Hand tool safety requires:
   _____ (PROPER TOOLS)
   _____ (TURN OFF POWER TO EQUIPMENT BEING SERVICED)
   _____ (PROTECT SHARP EDGES)
   _____ (CLAMP WORK AND HOLD TOOL WITH TWO HANDS)

4. A drill of 17/64 will drill a _____ mm diameter hole. (6.747 mm)

IV .1. POWER HAND TOOLS

Power hand tools are small hand-held tools, operated using mechanical or electrical power.

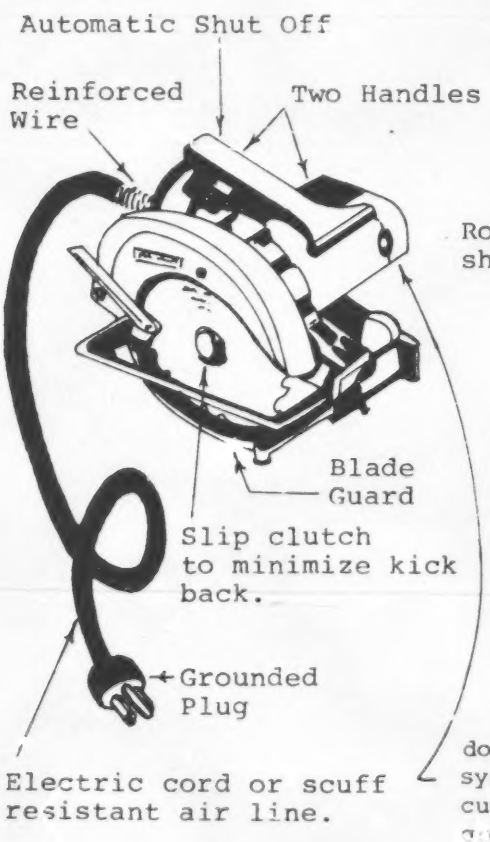
1. Safety

Power hand tool safety requires procedures and equipment which minimize the chance of accident. Best safety practice is to use procedures and equipment which require a minimum of two faults to cause injury. Before use, look for danger points and possible cases where safe guards may not be functioning. Power hand tools may be electrically, hydraulically or pneumatically (air) powered. Electric cords or lines to the tool must be kept clear of moving parts of the power tool.

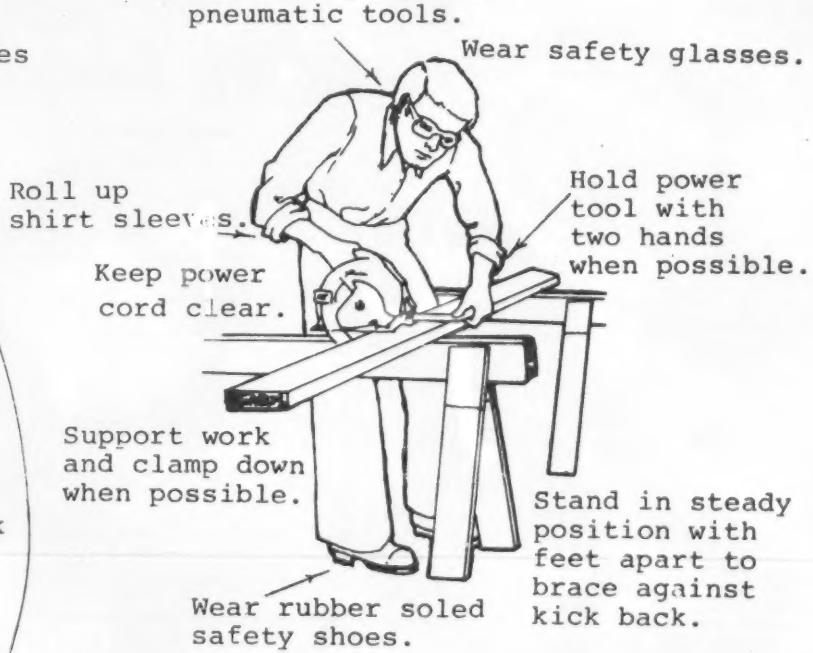
SAFETY PRACTICES

Good tools
Good mood
Plenty of light
Dry ground or area
When not hurried
When you feel productive and rested
Clean work area
Know equipment

EQUIPMENT SAFETY

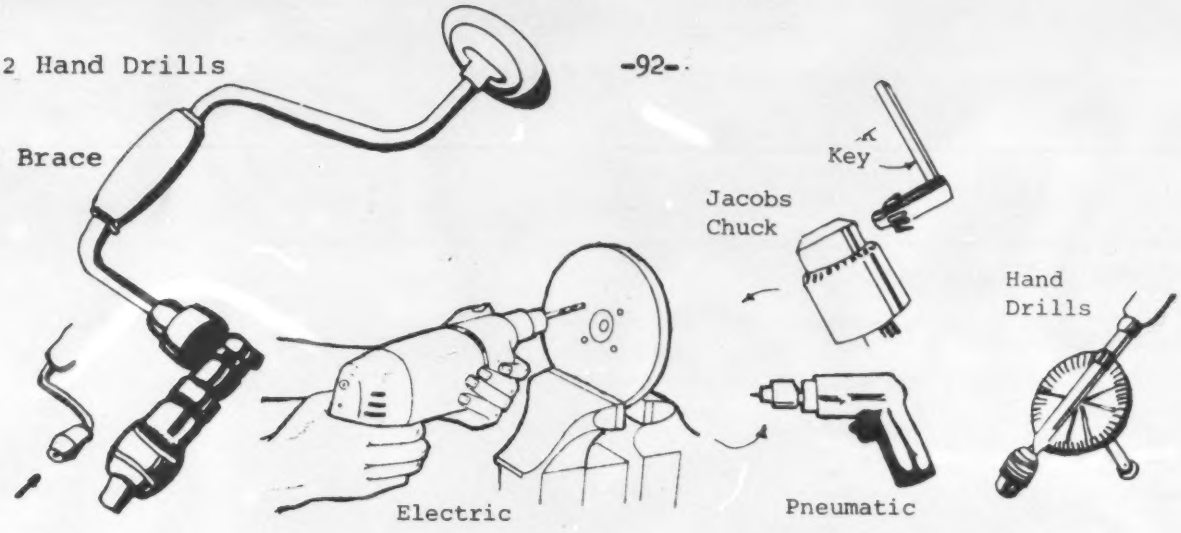

Automatic Shut Off
Reinforced Wire
Two Handles
Blade Guard
Slip clutch to minimize kick back.
Grounded Plug
Electric cord or scuff resistant air line.
doubly-insulated electrical system to prevent electrocution of operator from a ground fault.

OPERATOR SAFETY


Wear ear plugs for pneumatic tools.
Wear safety glasses.
Roll up shirt sleeves.
Hold power tool with two hands when possible.
Keep power cord clear.
Support work and clamp down when possible.
Stand in steady position with feet apart to brace against kick back.
Wear rubber soled safety shoes.

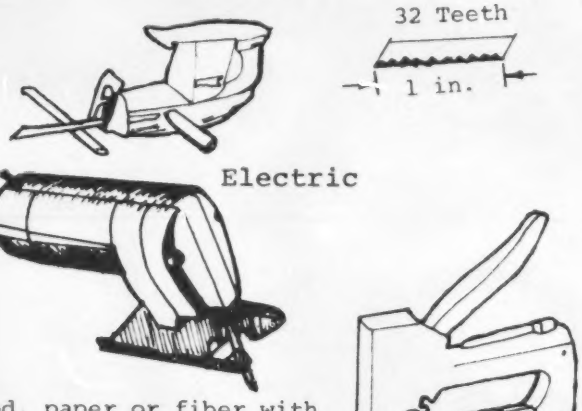
Tools must be strong and rigid enough to prevent breaking or binding.

IV.2 Hand Drills



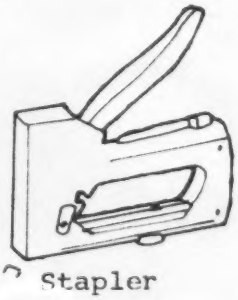
IV.3 SABER SAWS

Saber saws are used to cut steel, plastic, rubber and wood, producing intricate curved openings or holes using a reciprocating blade. Metal and thin work is cut using a fine tooth blade with 32 teeth/inch. Wood and metal 1/8" or greater 14 teeth/inch.



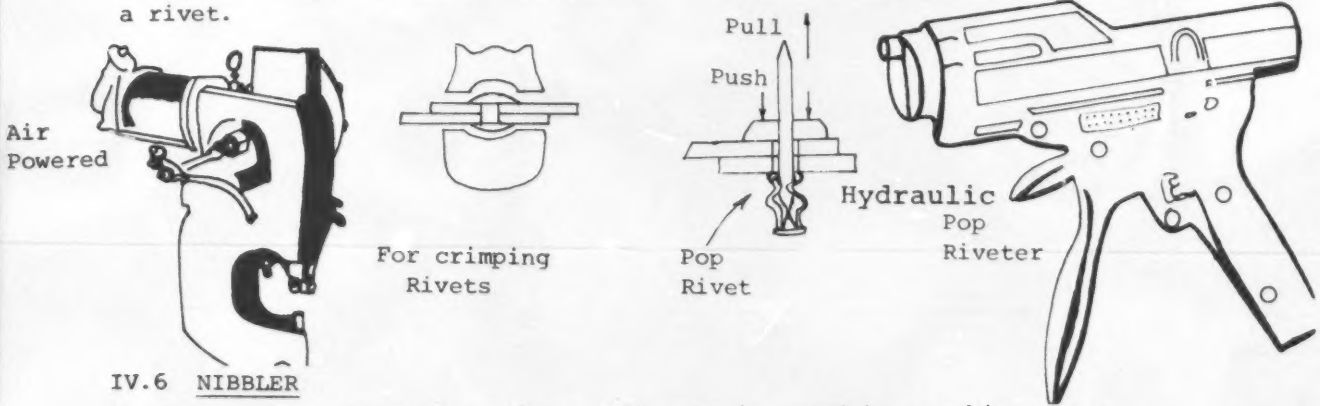
IV.4 STAPLERS

Staplers are used to fasten together wood, paper or fiber with wire staples or nails. A spring driven hammer drives the staple into the material.



IV.5 POWER RIVETING

Power riveting uses electric, hydraulic or pneumatic power to crimp a rivet.

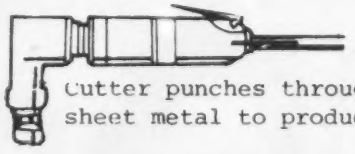


IV.6 NIBBLER

A nibbler is a shear that makes small cuts in metal by punching out a small piece of metal.

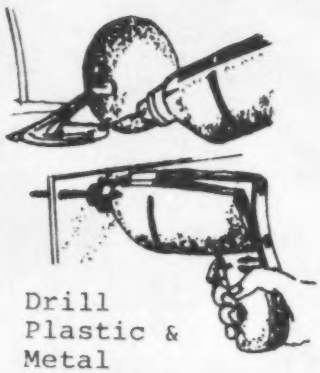
Nibblers are used to cut sheet metal up to 1/16 inch thick.

Nibblers can cut intricate shaped holes in large sheets starting from a drilled hole.

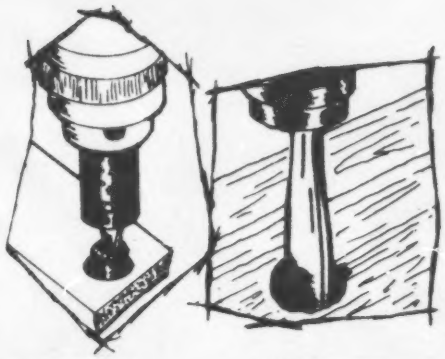


Operations done
with an electric drill.

Drill
Masonry

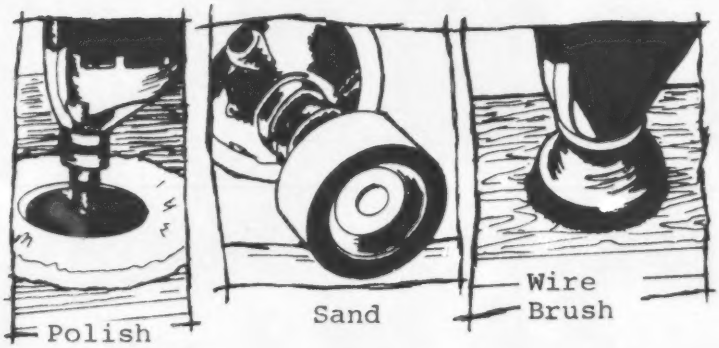


Drill
Plastic &
Metal



Drive
Screws

Bore
Wood



Polish

Sand

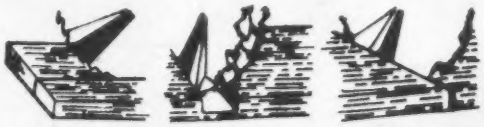
Wire
Brush

IV.1-6 LABORATORY

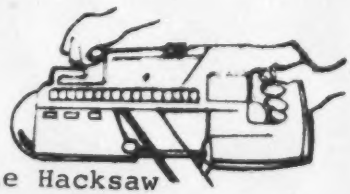
The student should learn safe operating procedures and proper care of power hand tools to minimize the chance of injury. The student will use power hand tools for making parts and developing safety habits. The student should gain knowledge of the type and uses of hand power drills by drilling wood, metal, plastic and masonry. He/she should gain knowledge of types and experience in the proper use of a saber saw. The student should know loading and proper use of power stapler. He/she should know identification and process of setting and crimping solid, tubular and pop rivets. The student should be able to identify and use a nibbler to cut thin metal sheet.

IV .7 POWER SAWS

For cutting wood, plywood,
plastic, and metal with proper cutting blades.



Rips Dadoes Miters



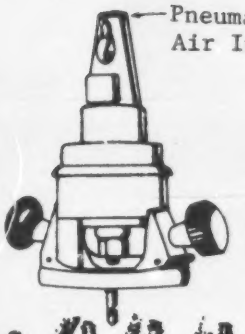
Portable Hacksaw

Cut Off

IV. 8 ROUTERS

A router is a high speed motor turning a cutter to cut different shapes.

Electric



Molding & Shaping Cuts

Groving & Trimming Cuts

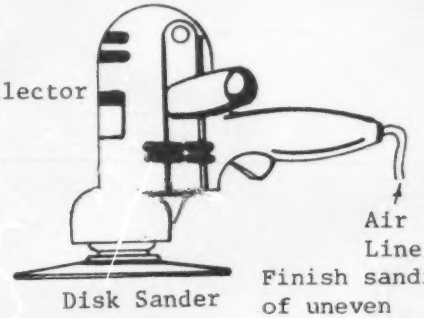
IV .9 SANDERS

Sanders use a moving abrasive surface made up of ceramic particles bonded to a backing sheet to remove material from a surface.

Belt Sander

Rough & finish sanding of large flat surfaces

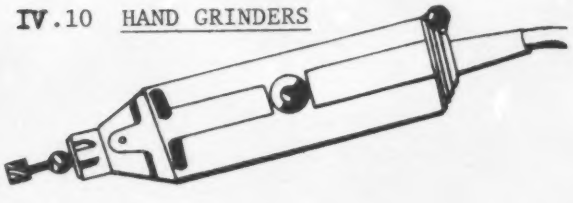
Orbital Sander



Disk Sander

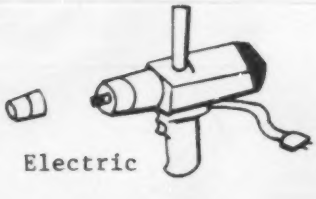
Finish sanding of uneven surfaces

IV.10 HAND GRINDERS

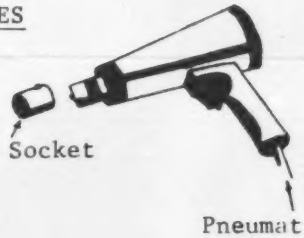


Hand grinders are used to deburr, grind, saw, and polish component parts of an assembly. Grinders turn from 12,000 to 25,000 RPM. Small grinding, cutting, and polishing wheels are mounted on $\frac{1}{8}$ or $\frac{1}{4}$ inch diameter shafts.

IV .11 IMPACT WRENCHES



Electric



Pneumatic Air

Impact wrenches are used to loosen or tighten nuts or bolted fasteners. A hammer action during rotation produces high turning torques with little torque on the operator.

IV.12 IMPACT HAMMER

Impact hammers rotate a drill or star drill and cause a pounding action towards the piece being drilled. Drilling holes in masonry and concrete for anchors is the main application.

DEMO-HAMMER For Heavy Duty Demolition Chiseling, etc.

LABORATORY

The student should be able to use hand power saws to cut wood, metal, and plastics. He/she should develop familiarity with components and operation of a router. He/she should be able to shape, trim or groove wood and plastics. The student should have knowledge of types and proper uses of sanders. The student should learn application of hand grinders to remove burrs and grind component parts of an assembly. He/she should have knowledge of types of and uses for impact wrenches in fabrication. The student must be knowledgable of the uses of impact hammers in drilling hard concrete or masonry.

IV. CHAPTER ITEMS

Worked Items

1. A minimal power hand tool selection for a science lab might include which tools?

   _____ (electric or pneumatic hand drill)

   _____ (saber saw)

2. Thicker pieces to be sawed can be cut with courser blades having fewer _____. (teeth per inch)

Student Items

1. List six basic safety practices when using power hand tools.

   (wear safety glasses, have good lighting, clamp work, hold tool with both hands, keep cords clear of work, be fresh and alert.)

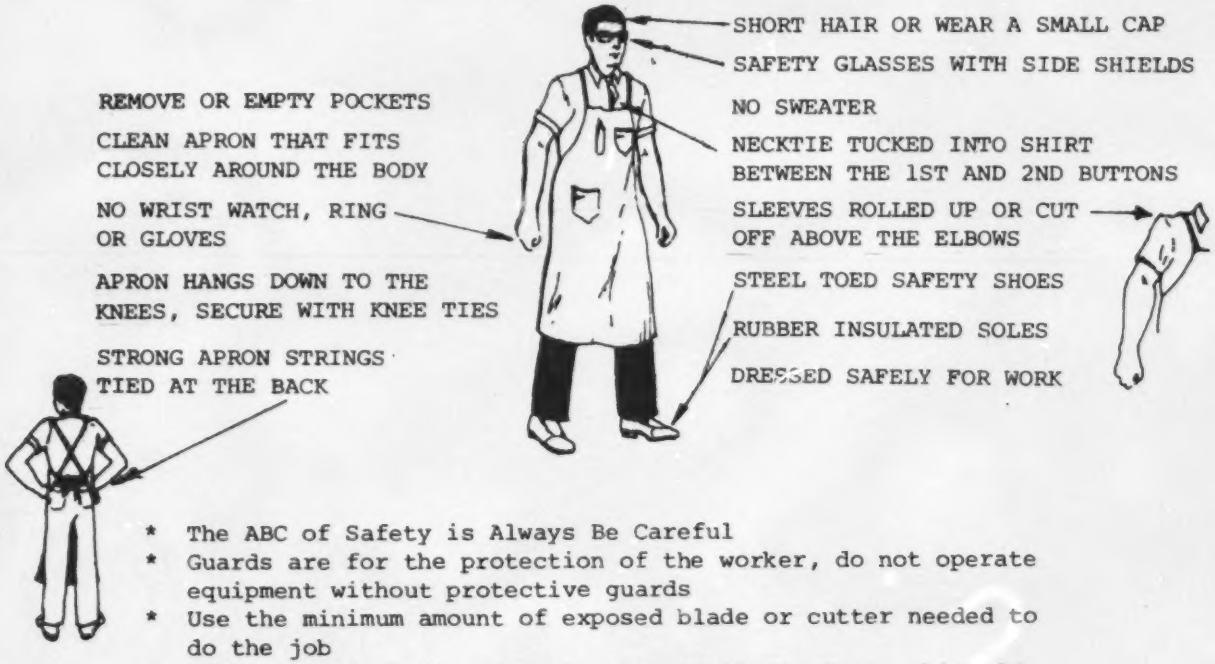
2. List four basic safety practices in the design of power hand tools.

   (rigid, durable power cord, guards on cutting edges, safety switch.)

V POWER BENCH TOOLS

V.1. SAFETY

Safe operation of power equipment must be a conceptual part of the workers attitude. A basic understanding of safe operating procedures will enable the worker to work safely without memorizing all of the many safety rules for each piece of equipment. The following concepts MUST be an integral part of the operator's safe work attitude.


SHORT HAIR OR WEAR A SMALL CAP
SAFETY GLASSES WITH SIDE SHIELDS
NO SWEATER
NECKTIE TUCKED INTO SHIRT BETWEEN THE 1ST AND 2ND BUTTONS
SLEEVES ROLLED UP OR CUT OFF ABOVE THE ELBOWS
STEEL TOED SAFETY SHOES
RUBBER INSULATED SOLES
DRESSED SAFELY FOR WORK
REMOVE OR EMPTY POCKETS
CLEAN APRON THAT FITS CLOSELY AROUND THE BODY
NO WRIST WATCH, RING OR GLOVES
APRON HANGS DOWN TO THE KNEES, SECURE WITH KNEE TIES
STRONG APRON STRINGS TIED AT THE BACK

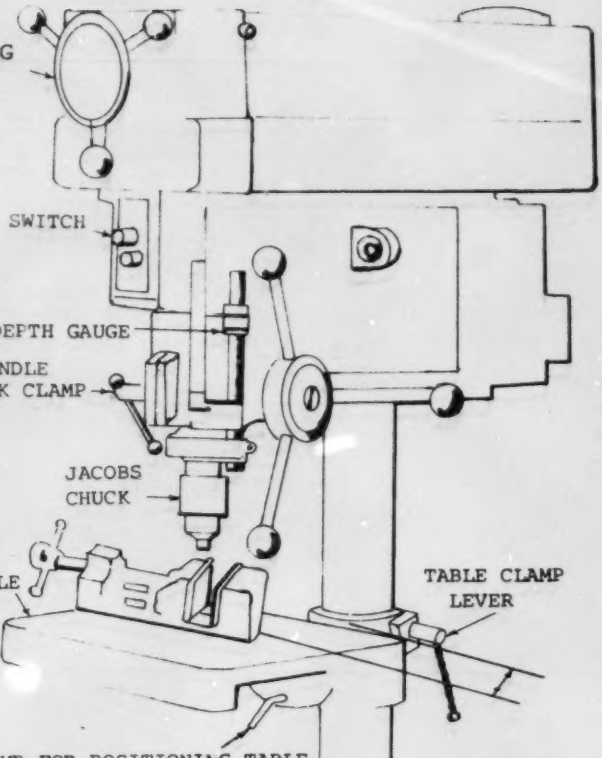
* The ABC of Safety is Always Be Careful
* Guards are for the protection of the worker, do not operate equipment without protective guards
* Use the minimum amount of exposed blade or cutter needed to do the job
* Machines and equipment have physical limitations, which if exceeded will not only overload the machine, but also pose a threat to the operator
* If it is not safe, don't do it
* For one's own protection it is necessary to wear & use the appropriate safety apparel
* One operator per machine
* Make machine adjustments when the equipment is not operating
* Machines should be rigidly mounted
* Follow safety procedures & rules for the machine or equipment being operated
* Keep areas around machines free of debris
* Select proper cutting tool, speed, feed and set up to do the job safely
* Keep hands, loose garments, tools, etc., away from moving parts
* Be sure to cut only the correct material
* Work safely for your fellow worker. Your fellow workers safety is your responsibility

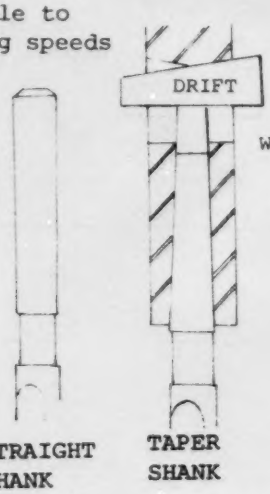
V.2 DRILL PRESS

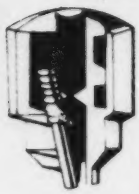
The drill press is used to drill, bore, and tap holes in materials with accurate positioning of the cutting tools.
Small drill presses hold only a straight shank drill in a Jacobs Chuck. Larger drill presses hold the drill with a self-locking taper shank. The drill is removed with a drift.

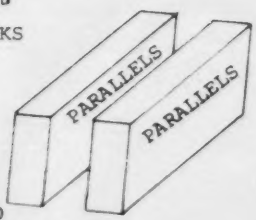
All work should be clamped to the worktable.

See published table to determine drilling speeds and feeds.

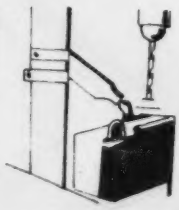




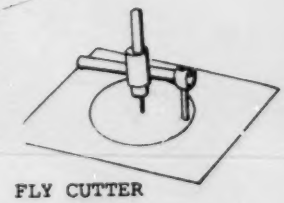

CHUCKS

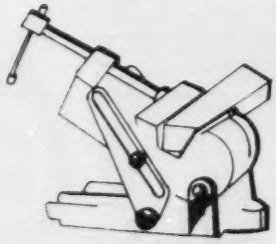


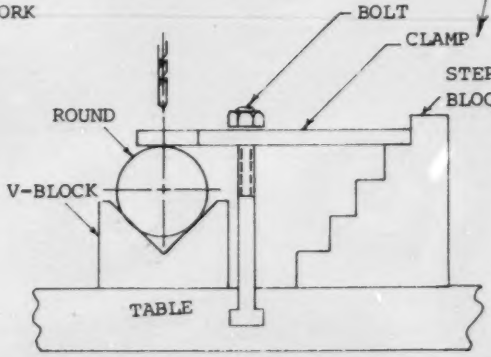
GROUND PARALLEL BARS ARE USED TO SUPPORT WORK

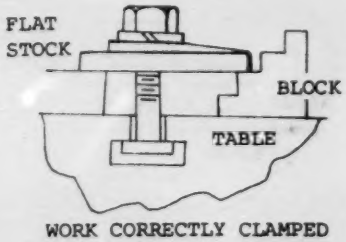


CLAMPING DEVICES


FLY CUTTER


ANGLE VISE





WORK CORRECTLY CLAMPED

SECTION ITEMS

1. Using published tables determine the drilling speed (SFPM) for drilling machinery steel with a 3/8 inch drill. _____. SFPM (110)

2. Using problem number 1 determine what the feed rate in inches per revolution should be. _____ inches per revolution. (.006)

3. The approximate rotational speed of a drill is in revolutions per minute (RPM). It is found using the following equation.

$$RPM = \frac{SFPM \times 4}{D}$$

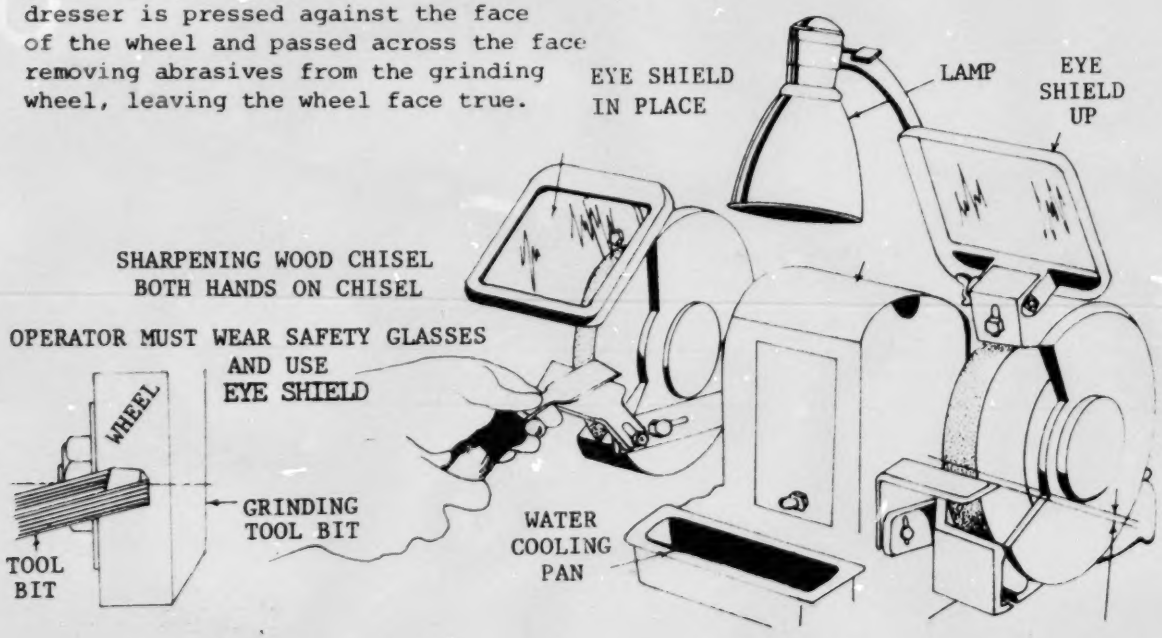
SFPM = surface feet per minute

D = drill diameter

For a 3/8 inch drill and SFPM of 110 determine the RPM.
_____ (1173. RPM)

V.3 GRINDER

Grinding machines or special purpose grinders are used to sharpen tools, to remove material that is too hard for machining, to polish surfaces to close tolerances and to cut hard metals. The bench grinder powered by an electric motor rotates two abrasive wheels. Tools to be sharpened are held against the face of the wheel as it rotates and abrasives within the grinding wheel cut particles from the tool to remove metal. This operation is known as tool sharpening. When the face of the grinding wheel becomes irregular, a wheel dresser is used to true the face of the wheel. As the grinding wheel rotates, the wheel dresser is pressed against the face of the wheel and passed across the face removing abrasives from the grinding wheel, leaving the wheel face true.



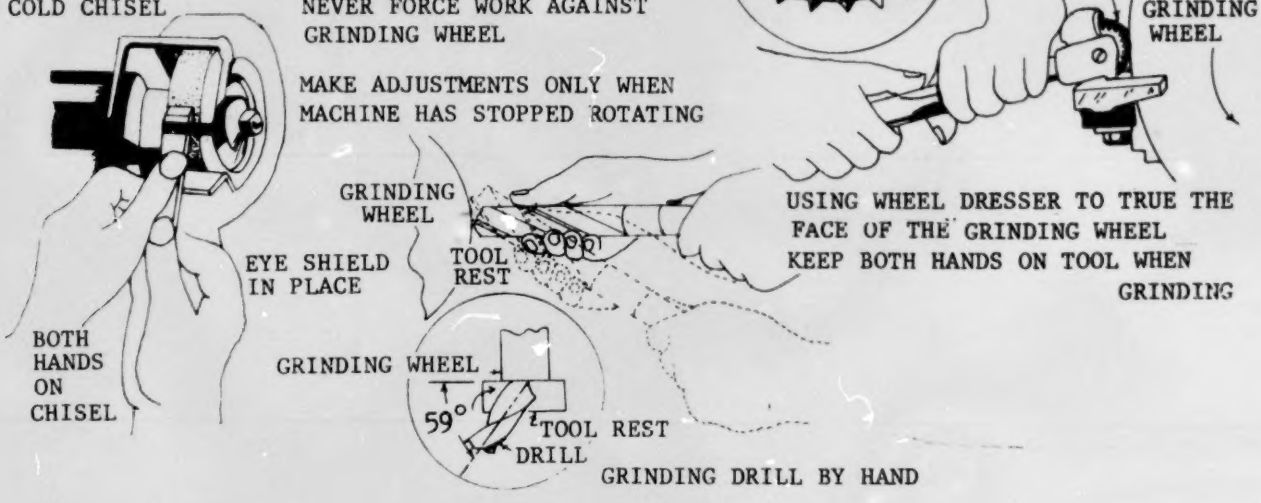
DO NOT STAND IN LINE WITH WHEEL ROTATION-ALWAYS STAND TO SIDE WHEN MACHINE IS FIRST TURNED ON. KEEP CLEAR OF FLYING PIECES IF THE WHEEL SHATTERS.

USE DUST ATTACHMENT TO EXHAUST PARTICALS

KEEP HANDS & LOOSE CLOTHING CLEAR OF THE ROTATING WHEELS

NEVER FORCE WORK AGAINST GRINDING WHEEL

MAKE ADJUSTMENTS ONLY WHEN MACHINE HAS STOPPED ROTATING

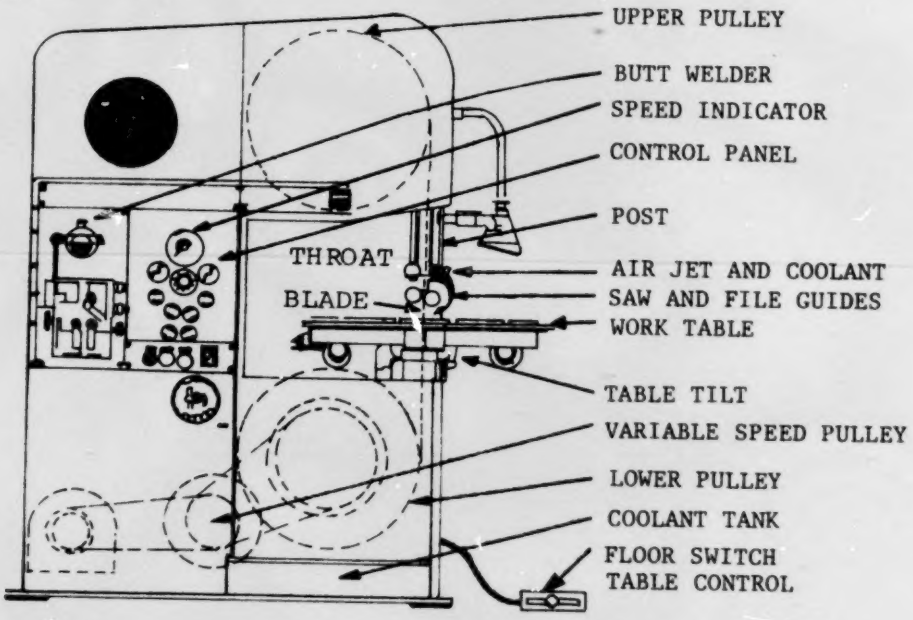


V. 4. BAND SAW

The band saw is used to cut and shape materials with minimum horsepower and least material waste. (See published tables for cutting blade data and operating speeds.)

TYPES

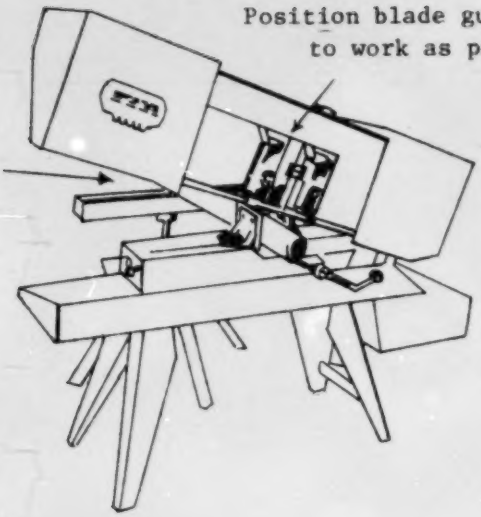
VERTICAL BAND SAW



HORIZONTAL
BAND CUT OFF SAW

Position blade guides as close to work as possible.

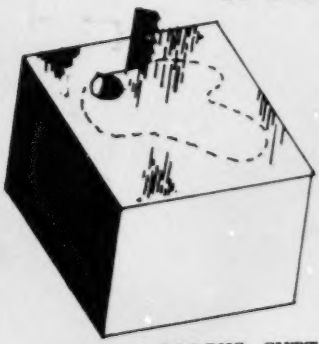
Lower blade slowly into work.



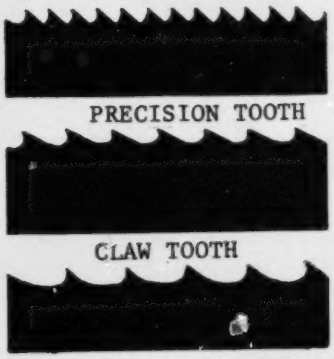
The band saw has many applications.

LESS HORSEPOWER REQUIRED

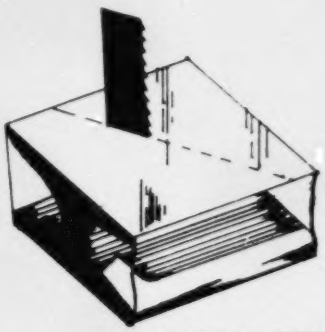
MINIMUM OF MATERIAL REDUCED TO CHIPS



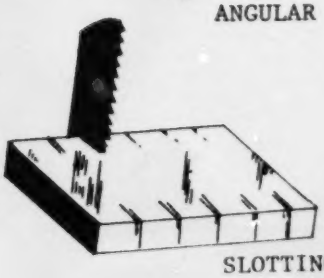
RADIUS CUTTING



LEAST MATERIAL WASTE

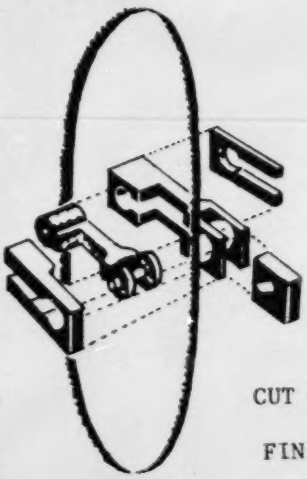


ANGULAR CUTTING

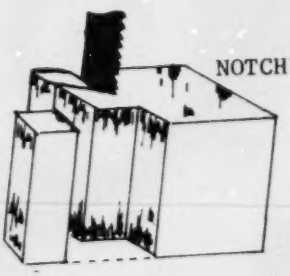


SLOTTING

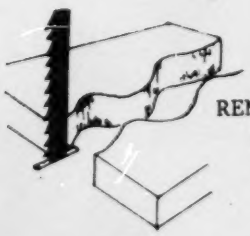
THREE-DIMENSIONAL CUTTING



CUT DIRECTLY TO FINISH LINE



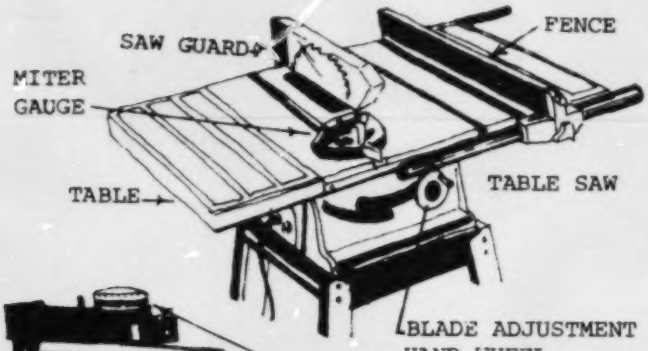
NOTCHING

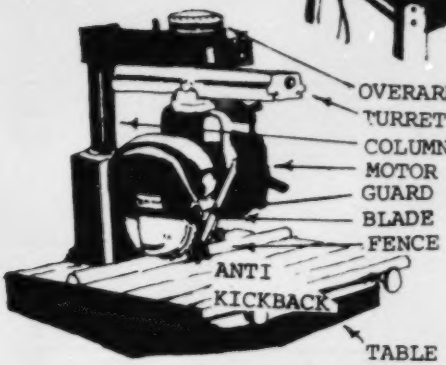


REMOVES WHOLE SECTIONS

BLADE WIDTH	RADIUS
1/2"	2 1/2"
3/8"	1 1/4"
1/4"	5/8"
3/16"	3/8"
1/8"	7/32"
3/32"	1/8"

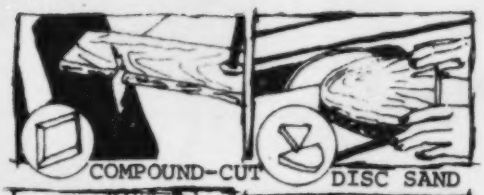
V.5. SAWS - TABLE & RADIAL

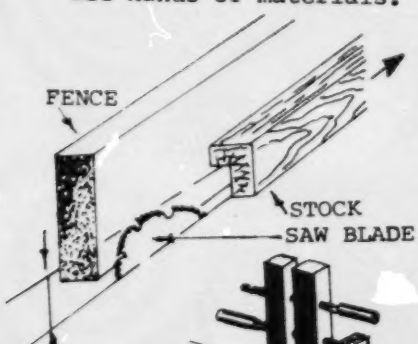


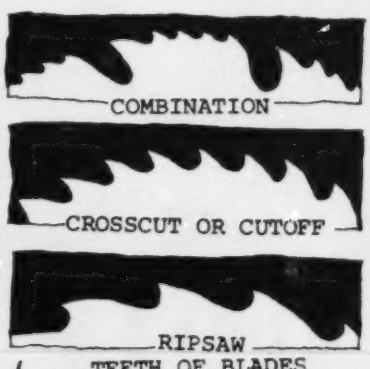


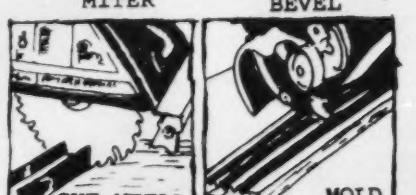
RADIAL SAW

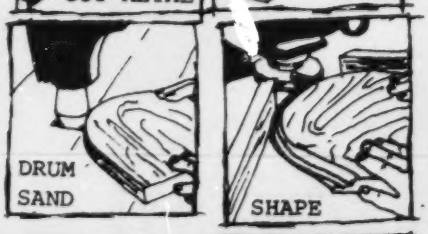
Circular or table saws and radial saws are used for crosscutting, ripping, joint cutting and making specialty cuts. A variety of attachments makes these saws highly valuable for cutting all kinds of materials.

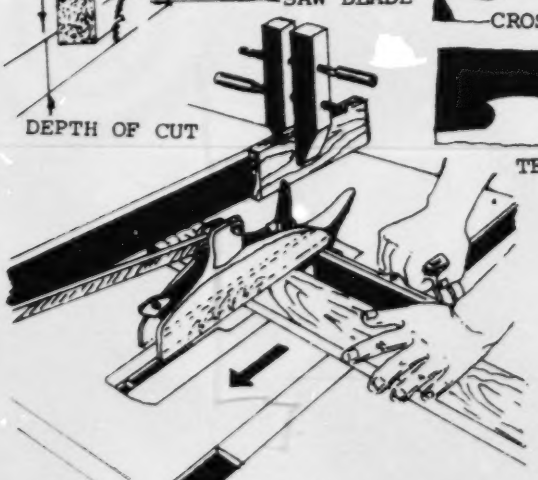




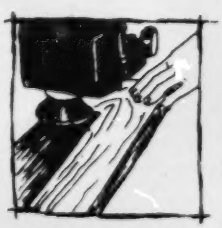






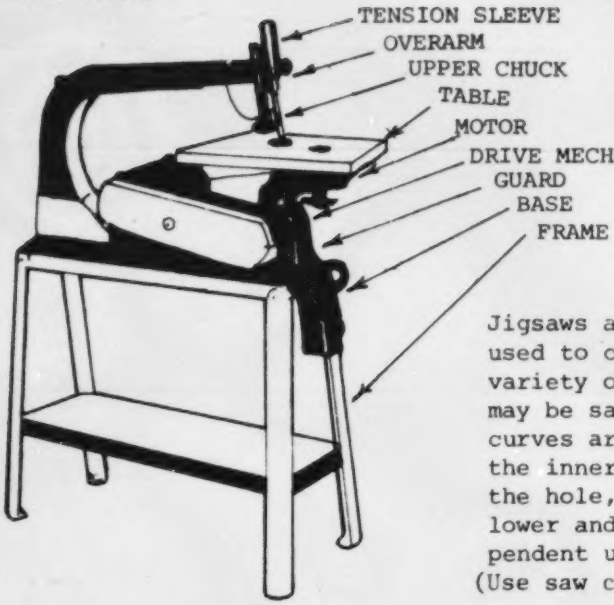


USING TABLE SAW TO CUTOFF STOCK



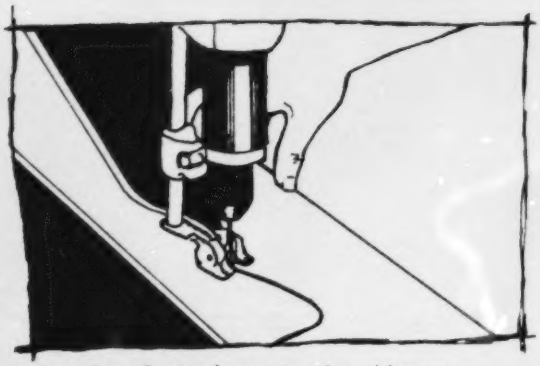
SURFACE PLANE

JIG SAWS



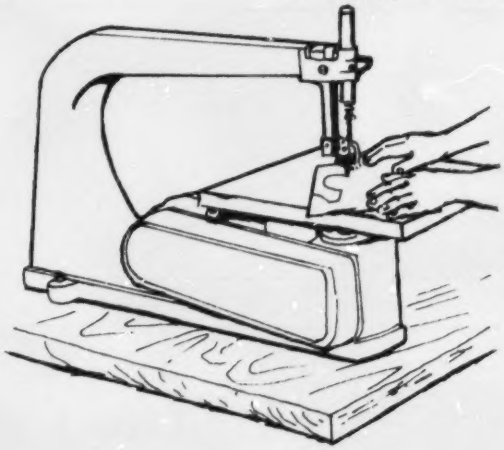
Principal parts of a jigsaw

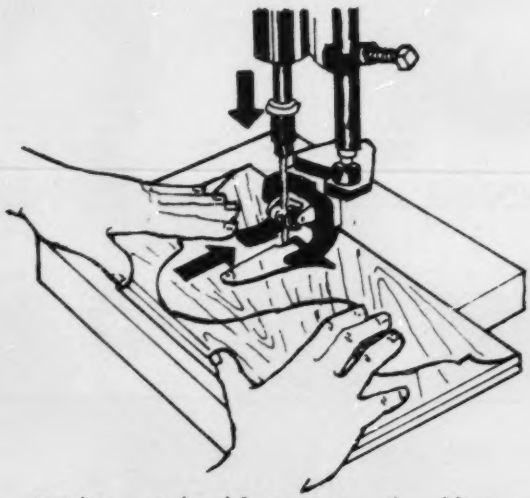
Jigsaws also known as scroll saws are generally used to cut irregular shapes. Using one of a variety of possible blades almost all materials may be sawed or filed to desired contours. Inside curves are easily cut by first boring a hole through the inner waste section, inserting a blade through the hole, then securing the blade ends in the lower and upper chucks. Blade selection is dependent upon stroke speed and material to be cut. (Use saw cutting speed charts for best cutting speeds.)



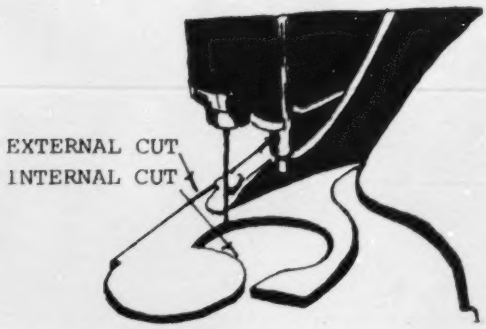
Freehand sawing on the jigsaw

RECIPROCAL MOTION

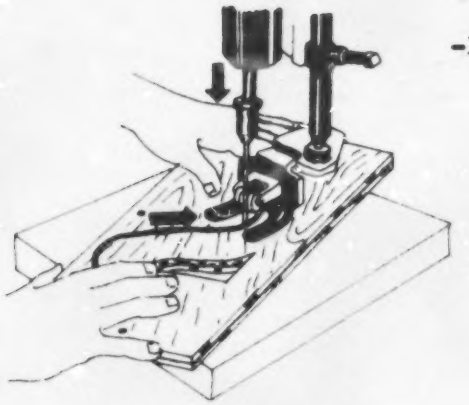




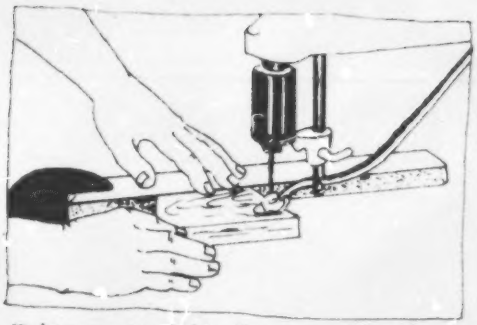
Making on inside cut on the jigsaw



External cuts determine the outer shape of a design



Cutting pieces on the jig saw.



Using a straightedge to guide the cut.

CUT	BLADE TEETH/INCH	BLADE SHAPE
SHARP CURVES, VENEER, & HARD & SOFT WOOD LESS THAN 1/8" THICK	—20	
MEDIUM CURVES, FIBER BOARD, PRESSED WOOD, & HARD & SOFT WOOD LESS THAN 5/8" THICK	—15	
LONG CURVES & HARD & SOFT WOOD LESS THAN 1" THICK	—10	

Jigsaw blades are 5" in length with a 5/8" blank on each end. The teeth per inch and width of the blade depend on the cut.

An extra guide is required, since the saber blade is held only by the lower chuck.

SECTION ITEMS

1. A band saw blade 3/8 inch wide will cut a radius of _____ inches. (1.25)
2. The cutting speed for a band saw cutting low carbon steel without coolant is _____. (125 SFPM)
3. A band saw has a blade that wanders. List the five items that might cause the problem.

_____ (blade tension)

_____ (feed heavy)

_____ (blade tracking)

_____ (guides far apart)

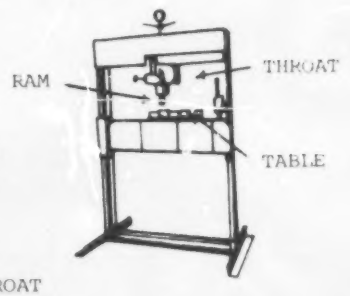
_____ (blade dull on one side)

V. 6. ARBOR PRESS

The Arbor Press is used to apply force to a part for bending, straightening, or pushing.

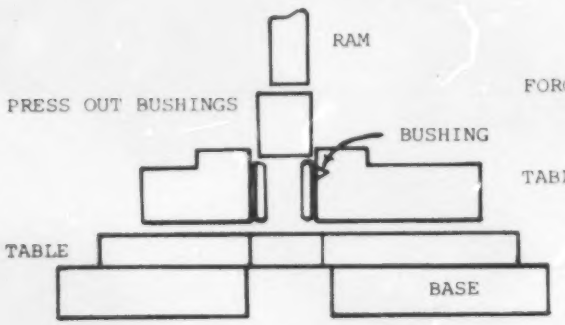
The Arbor Press should not be over loaded. Lengthening the handle with a lever may cause failure of the press. The operator should not hang on the handle but apply a steady pull keeping feet on the floor.

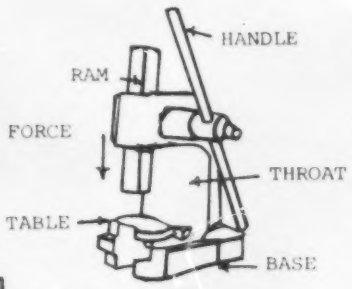
PRESS CAPACITY IS IN TONS OF FORCE



HYDRAULIC ARBOR PRESS

APPLICATIONS OF AN ARBOR PRESS





HAND ARBOR PRESS

OTHER USES INCLUDE

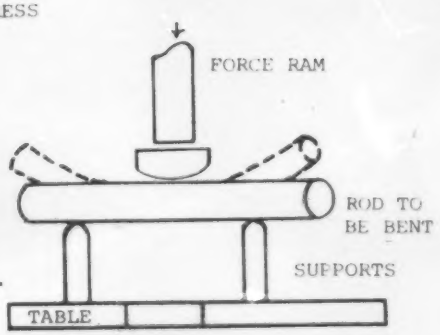
Pressing out roll pins.

Pressing in bearings or seals.

Broaching key ways in pulley or gear hubs.

Pressing hubs on mandrals for turning between centers.

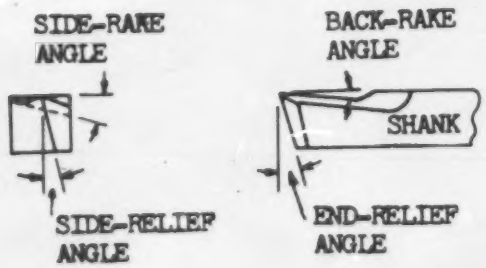
Bending heavy metal parts to shape.

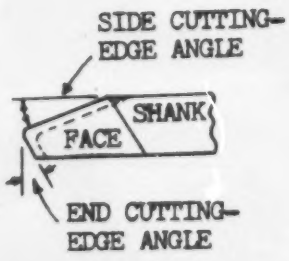


V. 7. METAL LATHE

Cutting Tools

Angles Vary For Different Materials



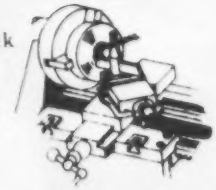


LATHE (METAL)

Lathes Machine

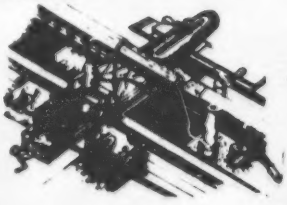
Cylindrical Surfaces

Facing
3 Jaw Chuck



Taper Turning
Between Centers

Cutter



Turning
Between Centers

Lathe
Dog

Face Plate

Work

Center

Center

Reaming

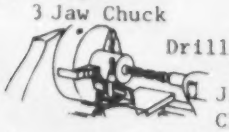
3 Jaw
Chuck

Reamer

Jacobs
Chuck

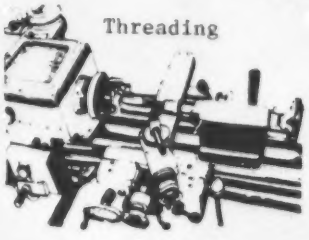
Drilling
3 Jaw Chuck

Drill

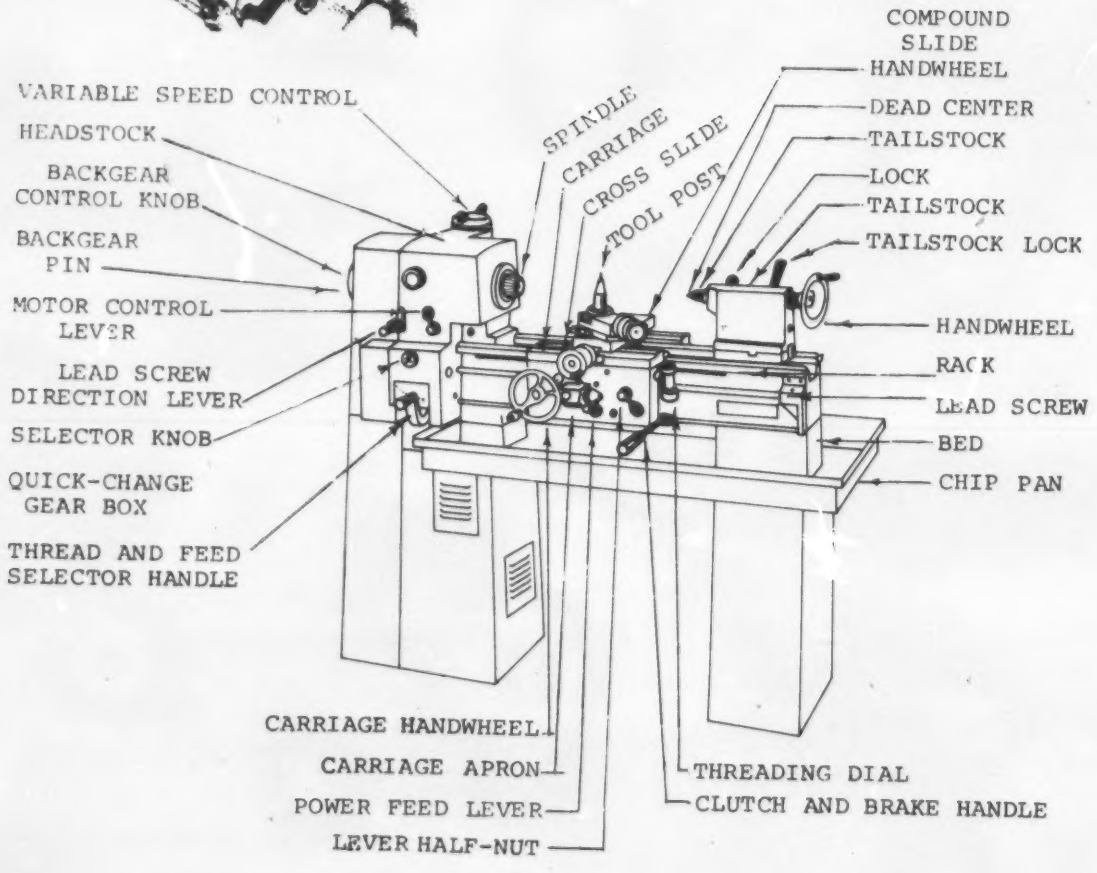


Jacobs
Chuck

Threading



Knurling
3 Jaw and
Live Tail Stock Center

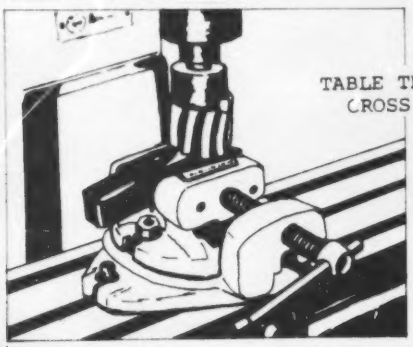


V.8. VERTICAL MILLING MACHINE

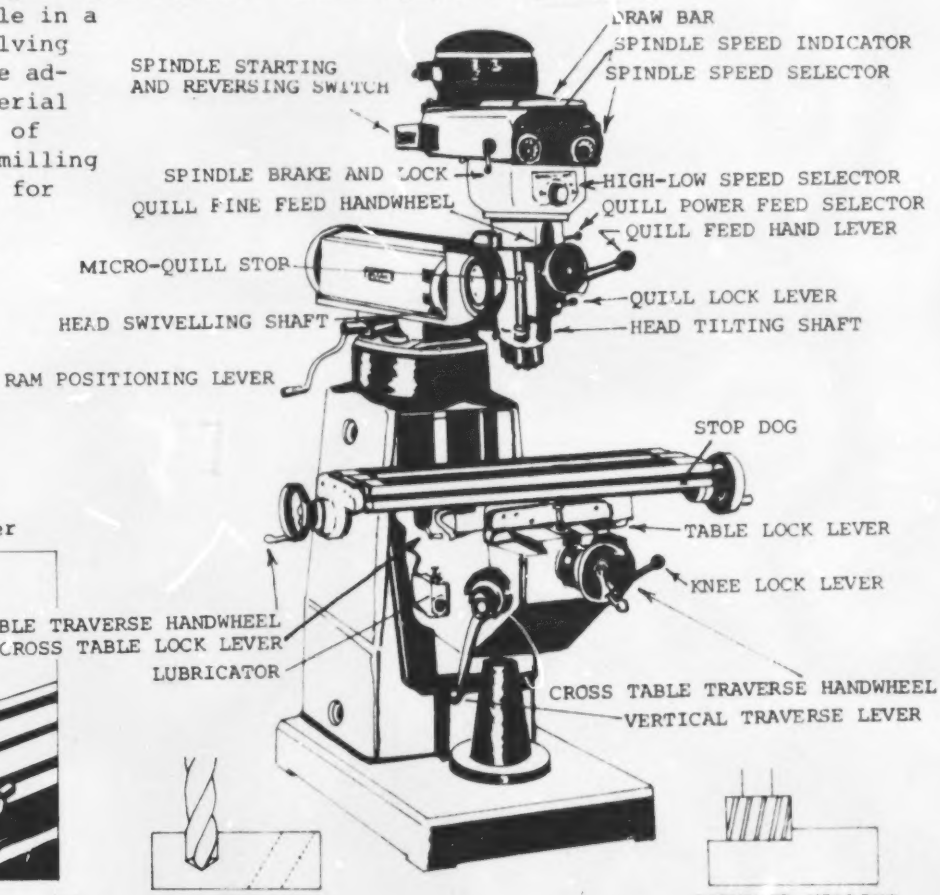
Milling machines are machine tools used to produce plane and formed surfaces. The cutting tool is a multiple tooth cutter. The workpiece is generally mounted on the machine table in a vise and fed into the revolving cutter. Cutting speeds are adjusted for the kind of material being machined. A variety of cutters are available for milling many kinds of surfaces and for performing many different kinds of mill operations.

See tables for cutting speeds, feeds, and formulas.

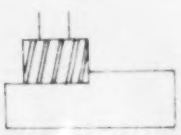
Woodruff key and keyseat cutter



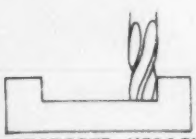
Machining a Flat Angular Surface with Shell-End Mill



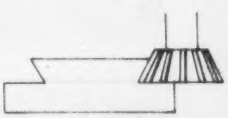
HOLE DRILLING



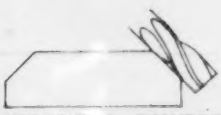
SHOULDER MILLING



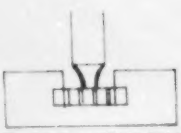
RECESSED MILLING



MILLING A DOVETAIL



MILLING A CHAMFER



T-SLOT MILLING

MILLING A GROOVE

SECTION ITEMS

1. A 2 inch diameter steel bar is to be turned. What RPM should the lathe spindle run? _____(180-200)
2. Cutting tool nomenclature is shown in textbook. What angles should be used in sharpening a lathe bit to turn low carbon steel?
   side rake angle _____(10^{o}) end relief angle _____(10^{o}) side relief angle _____(10^{o})
3. Calculate the RPM of a 1" diameter two flute end mill cutting low carbon steel. _____(229 RPM)
4. Using problem 3 and data from textbook determine the proper feed rate in inches per minute. _____IMP (2.29)IMP

LABORATORY - CHAPTER V

1. The student should develop safety procedures for operating power bench tools, and proper attitudes for safe practices.

2. The student should learn names of drill press components and of accessories used on the machine, and should use the machine to do drilling operations on plastic, metal, and wood projects.

3. The student should know proper operation and different applications of the bench grinder and be able to sharpen a screw driver, a lathe bit, a chisel, and a center punch.

4. The student should learn component names and procedures to safely run vertical and horizontal band saws and practice by cutting metal, plastic, and wood.

5. The student should learn components and operation of a table saw and jig saw.

6. The student should learn proper use of an arbor press for straightening, pushing, or bending.

7. The student should learn basic lathe terminology and setups for machining different cyslindrical surfaces and be able to machine threads. He/she should be able to calculate approximate turning speed using

$$RPM = \frac{SFPM \times 4}{D}$$

D = Diameter of work. SFPM = Speed work passes cutter in surface feet per min.

8. The student should learn terminology and application of the vertical milling machine to fabricate parts with flat or cylindrical surfaces.

END OF CHAPTER PROBLEMS

WORKED PROBLEMS

1. A drill press is used to drill a 5/8 inch hole in brass. What RPM should be used? _____

   From text book Drilling Brass - SFPM = 200 - 250

   $RPM = \frac{SFPM \times 4}{D}$ D = 5/8 inches. $RPM = \frac{200 \times 4}{5/8} = (1280\ RPM)$

2. A .750 inch diameter rod of aluminum is to be turned in the lathe. What RPM should the spindle turn? _____

   Using text book For Aluminum - SFPM = 200 - 1500

   $RPM = \frac{SFPM \times 4}{D} = \frac{200 \times 4}{.75} = (1067.\ RPM)$ UP TO $\frac{1500 \times 4}{.75} = (8000\ RPM)$

   Speed will be limited by the heat generated and how badly the aluminum galled.

STUDENT PROBLEMS

1. Find the spindle speed for turning a 2.5 inch diameter fiber drum on the lathe. _____ (128 RPM)

2. A 1 3/8 inch hole is to be drilled in an aluminum plate. What RPM should it turn? _____ (582 RPM)

VI. METAL FABRICATION

VI.1. SAFETY

Metal fabrication requires both safe dress and safe working procedures. Safe dress includes:

1. Safety glasses for protection from springs or loose chips which may fly from equipment.
2. Safety shoes for protection from dropped parts or sharp tools.
3. Short sleeved shirt near rotating equipment. No rings or ties.
4. Electrical insulation to minimize shock hazard.
5. Hard hat when working in or below part of equipment.

Safe procedures include:

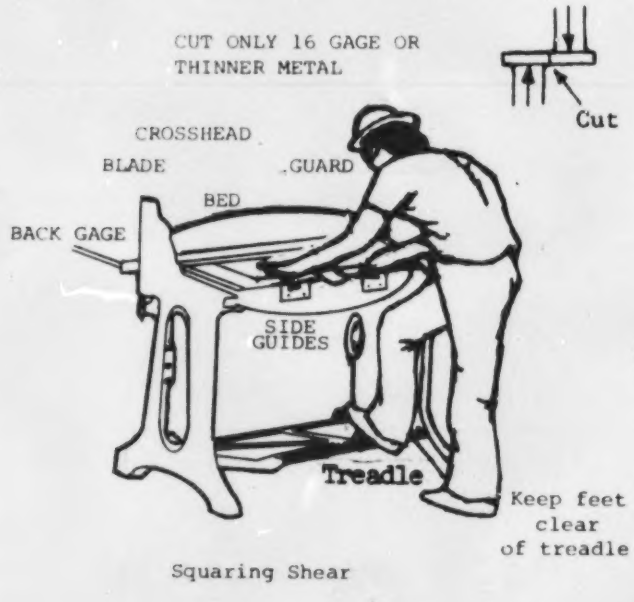
1. Only one man operates a machine at one time.
2. Turn off power, disconnect or lock out power source.
3. When using flame, always have a fire extinguisher available.
4. Gloves and apron as heat protection when welding or soldering.
5. Never use open flame near flammable materials.
6. Never push machine away from body to guard against slipping or falling.
7. Remove burrs and sharp edges from parts to prevent scratches and cuts.
8. Always get prompt medical aid for burns, scratches, cuts or splinters.
9. Do not stand in path of chips.

LABORATORY

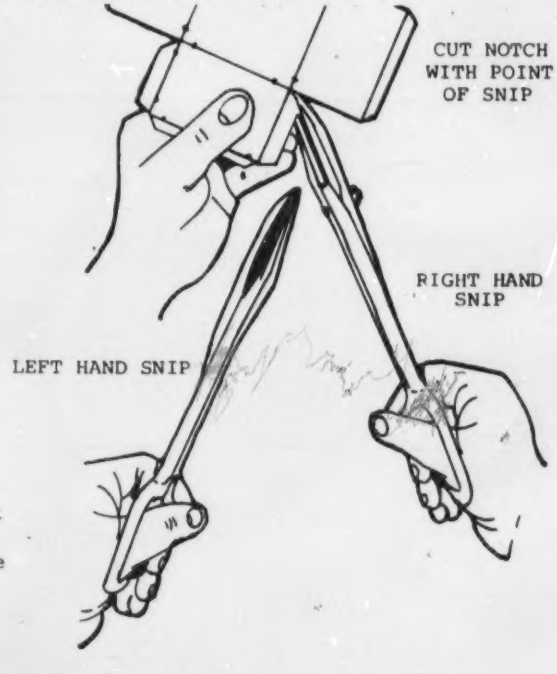
The student should develop safe working habits when fabricating and assembling parts of metal.

IV.2 SHEARING

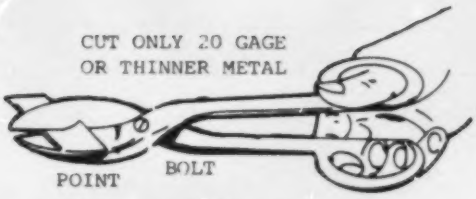
Shearing is the process of cutting materials between two cutting edges.



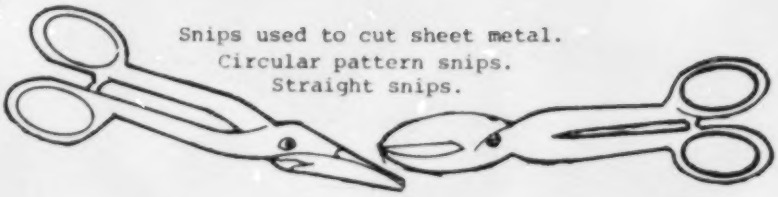
Squaring Shear



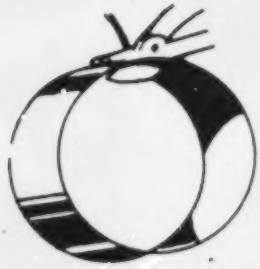
Using Hawk's Bill Scroll Snip

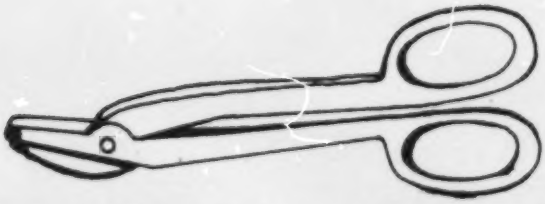


Using Snips

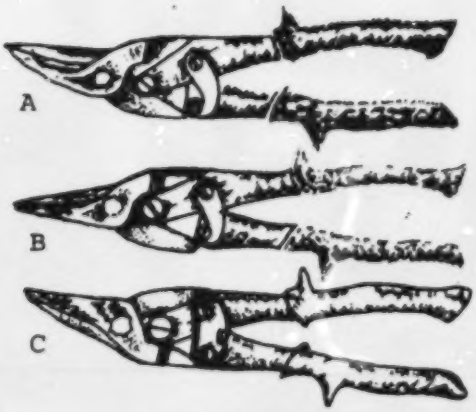


Snips used to cut sheet metal.
Circular pattern snips.
Straight snips.

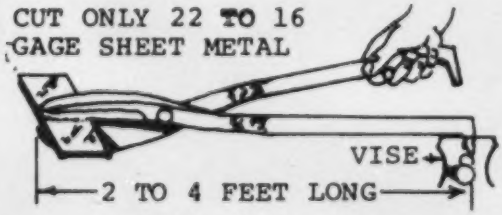




Using Double-Cutting Shear to Cut a Cylinder



Aviation Snips
A. Cuts Left
B. Cuts Straight
C. Cuts Right



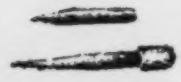
Bench Shear

LABORATORY

The student should shear sheet metal using a number of shearing methods in the fabrication of projects.

VI-3 PUNCHING

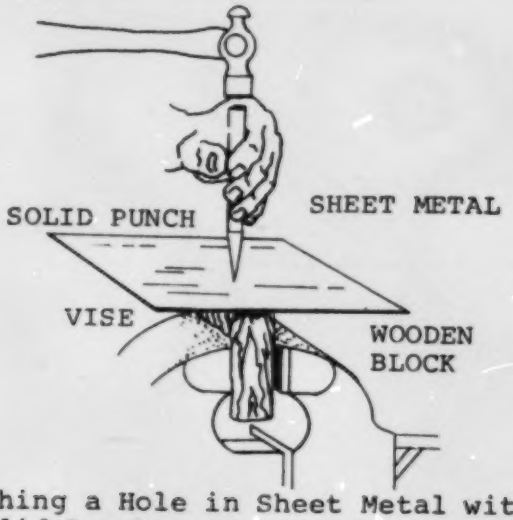
Punching is the operation of shearing to produce a mark or hole.



CENTER PUNCH

HOLE PUNCH

SOLID PUNCH

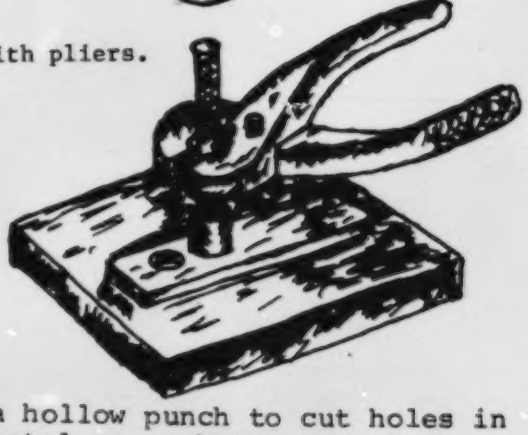


Punching a Hole in Sheet Metal with a Solid Punch

HOLLOW PUNCH

Hold punch with pliers.

SHEET METAL HAND PUNCH



Using a hollow punch to cut holes in sheet metal or gaskets.

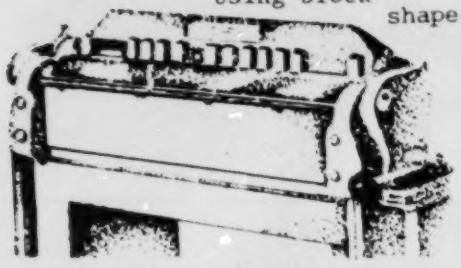
LABORATORY

The student should use a number of punching methods in the fabrication of metal parts.

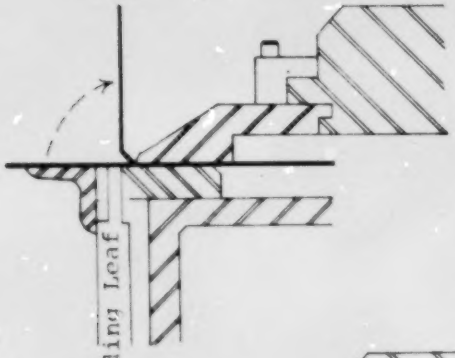
VI 4 BENDING SHEET METAL

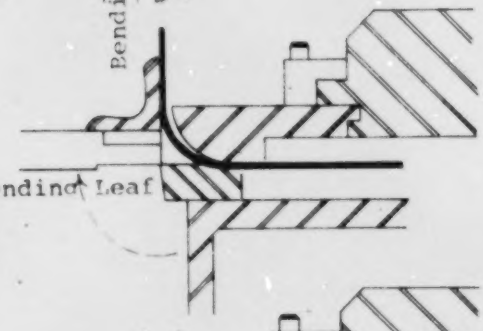
Bending is the process of forming metal to a desired shape by using blocks, guides, clamps or fixtures.

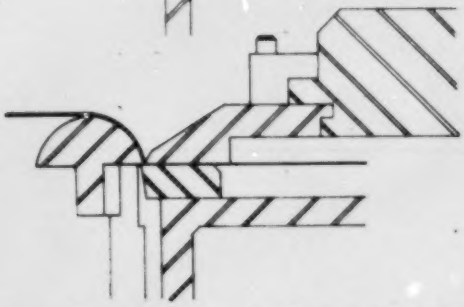
Using block



Box and pan brake

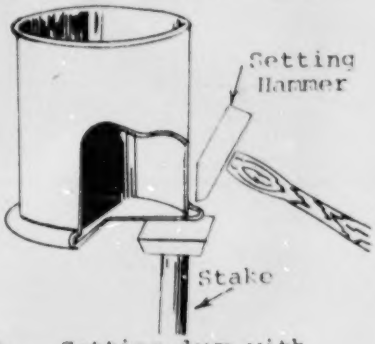




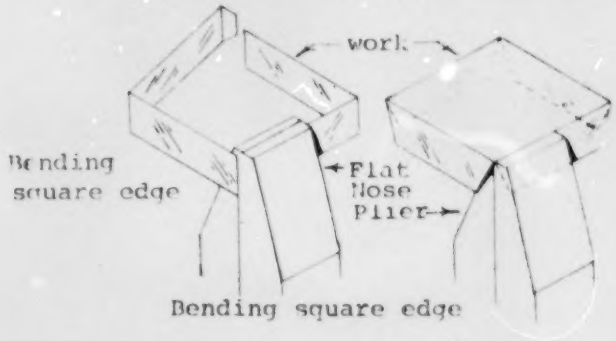


Forming blocks in place on brake

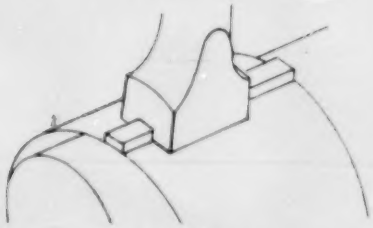
Forming on edge with hand seamer.



Setting down with a setting hammer

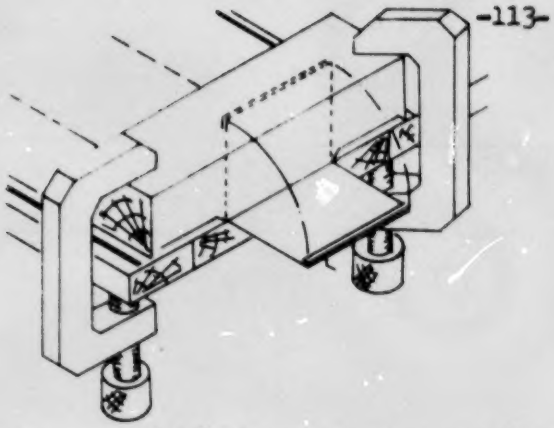


Bending square edge

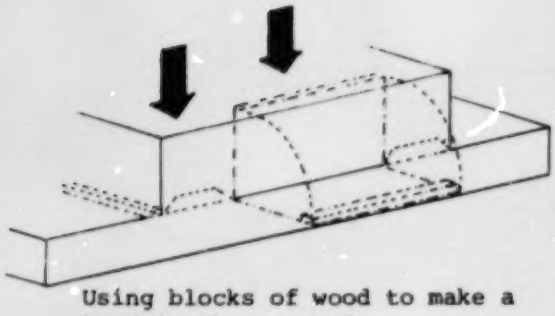


Using hand groover to set a seam

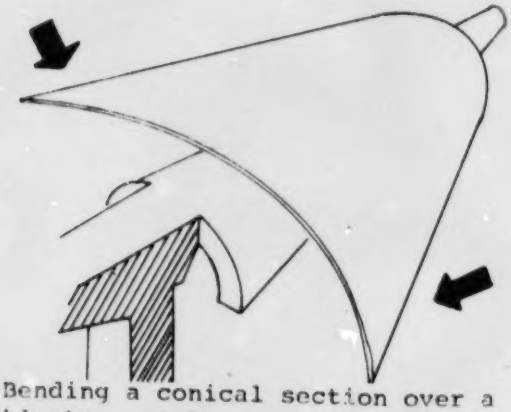
Making a hemmed edge. (A) Adjust depth gauge to size (B) Make the Fold. (C) Flatten fold



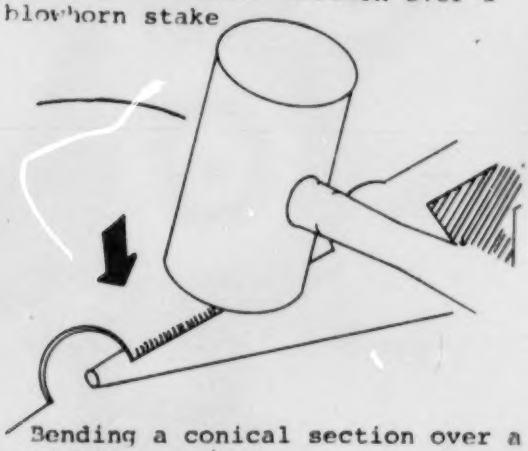
Using a wood block to make an angular bend.



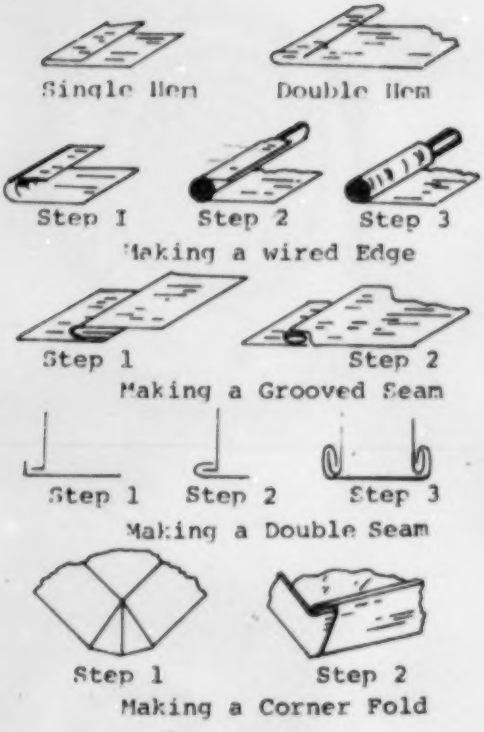
Using blocks of wood to make a bend in sheet metal



Bending a conical section over a blowhorn stake



Bending a conical section over a blowhorn stake.



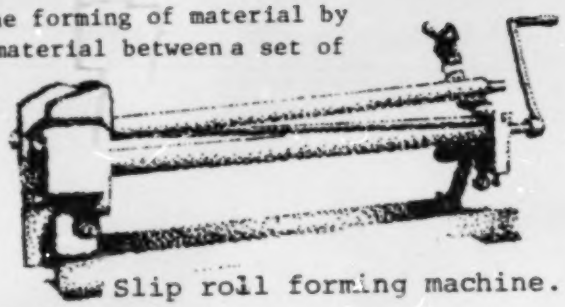
HEMS AND SEAMS

LABORATORY

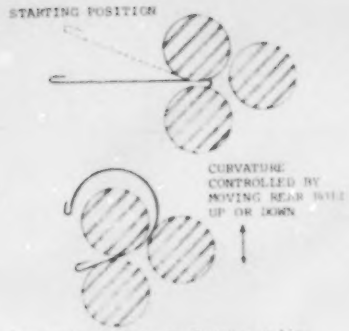
The student should do bending of sheet metal and strap iron in the fabrication of boxes, ducts, or brackets.

VI-5 ROLLING

Rolling is the forming of material by bending the material between a set of three rolls.



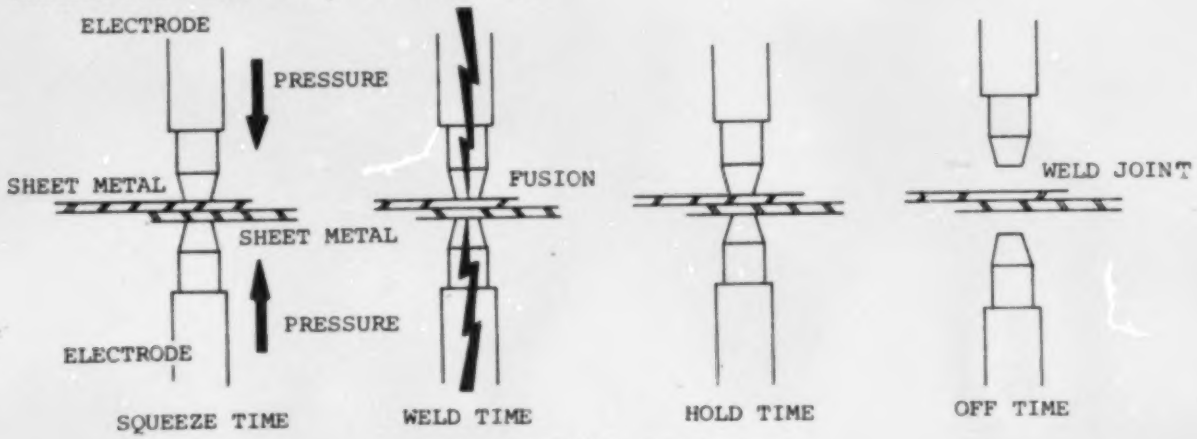
Slip roll forming machine.



Forming cylinders on forming rolls.

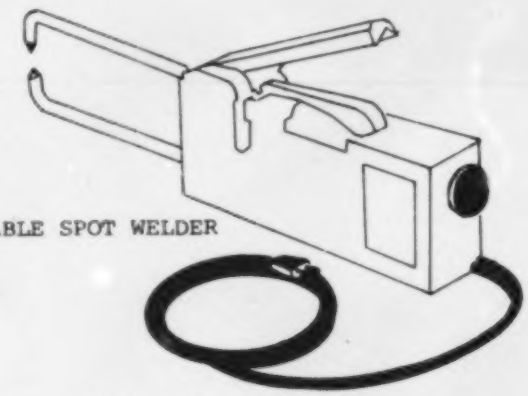
VI-6. SPOT WELDING

Spot welding is resistance welding in which metals to be welded are clamped between two electrodes. The electric current is passed between the two electrodes and the electrical resistance of the metal between the electrodes heats the metal at the point of contact and fuses the pieces together.



Spot welding sequence.

Metals to be welded must be clean and in full contact for good weld. Also, proper current and time of application must be used.



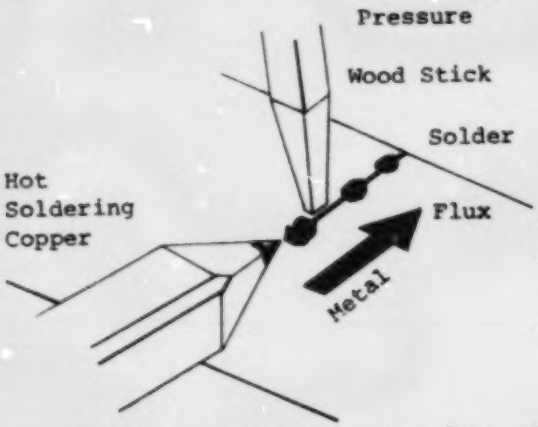
PORTABLE SPOT WELDER

LABORATORY

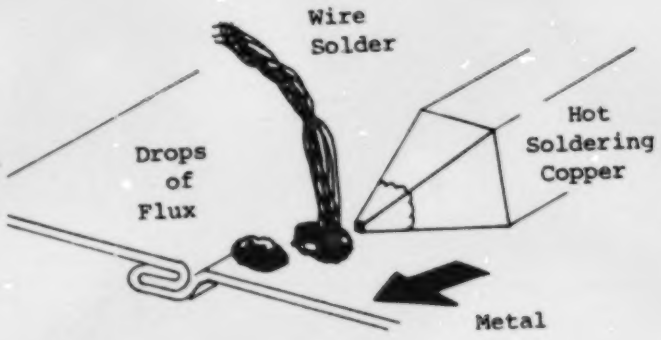
The student should use a slip roll to form cylindrical components of sheet metal and rod. The student should fabricate a part using a spot welder.

VI-7 SOLDERING SHEET METAL

Soldering is the bonding of two or more pieces of metallic material using a low melting point, non-ferrous alloy. The bond is mechanical and requires surfaces clean and free of metal oxides. Flux, a rosin or weak acid, assists in removal of oxides.

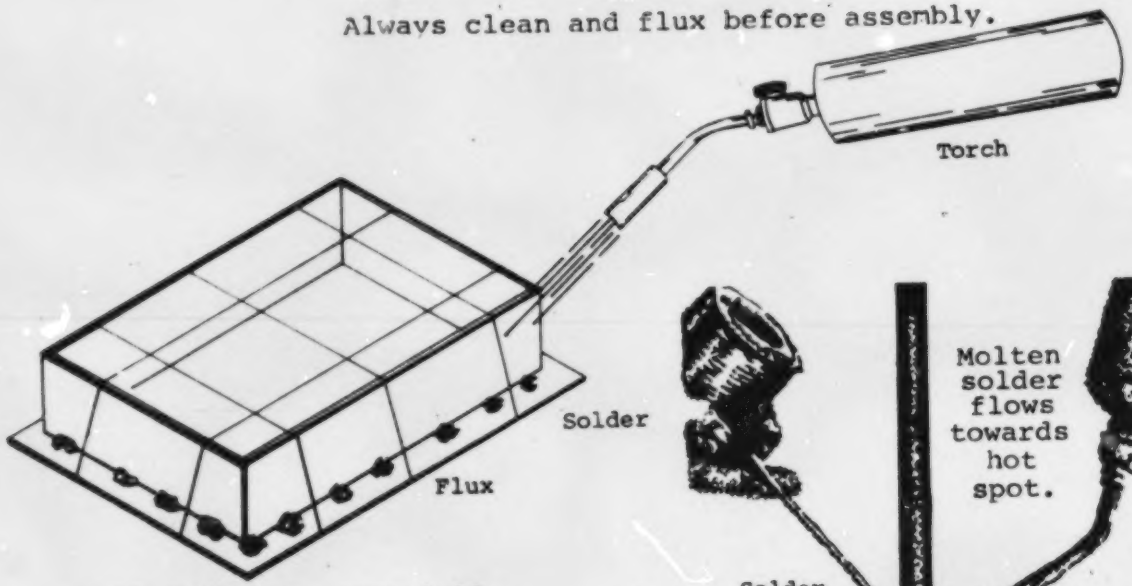


Hold sheet metal pieces together until the molten solder solidifies

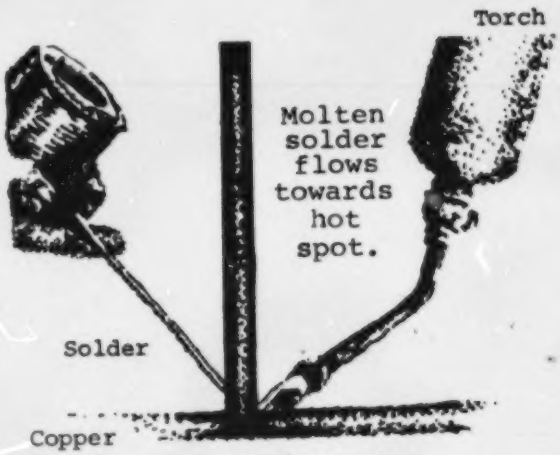


Molten solder always flows towards hot copper.

Always clean and flux before assembly.



Torch Soldering - parts held together with soft iron wire.



Gas torch soldering with heat.

Clean & preflux surfaces before heating.

Torch soldering

Applying solder at edge of joint.

Braze up to 1/4" thick steel

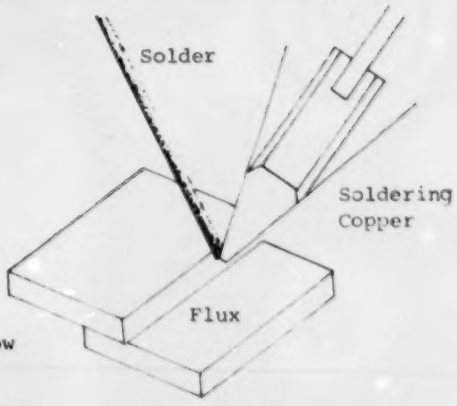
Heat Shield

Shield reduces heat lost.

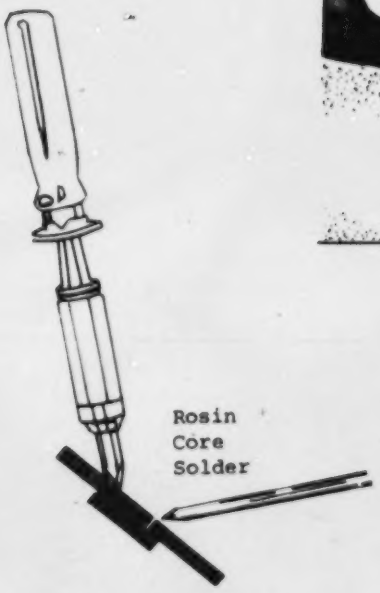
Sweat soldering a joint.

Apply heat at corner.

Solder will flow towards heat.



Lap Joint



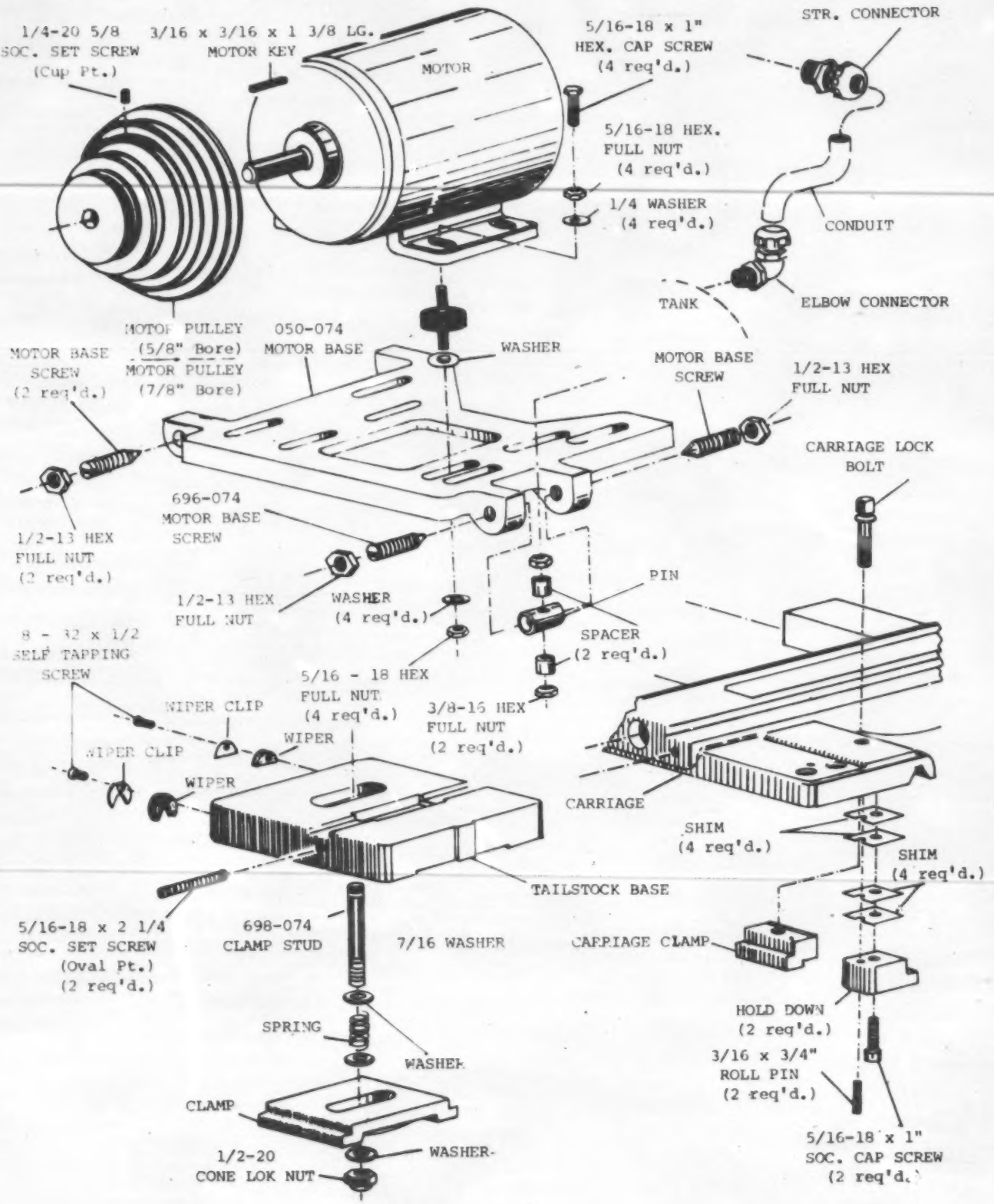
Rosin Core Solder

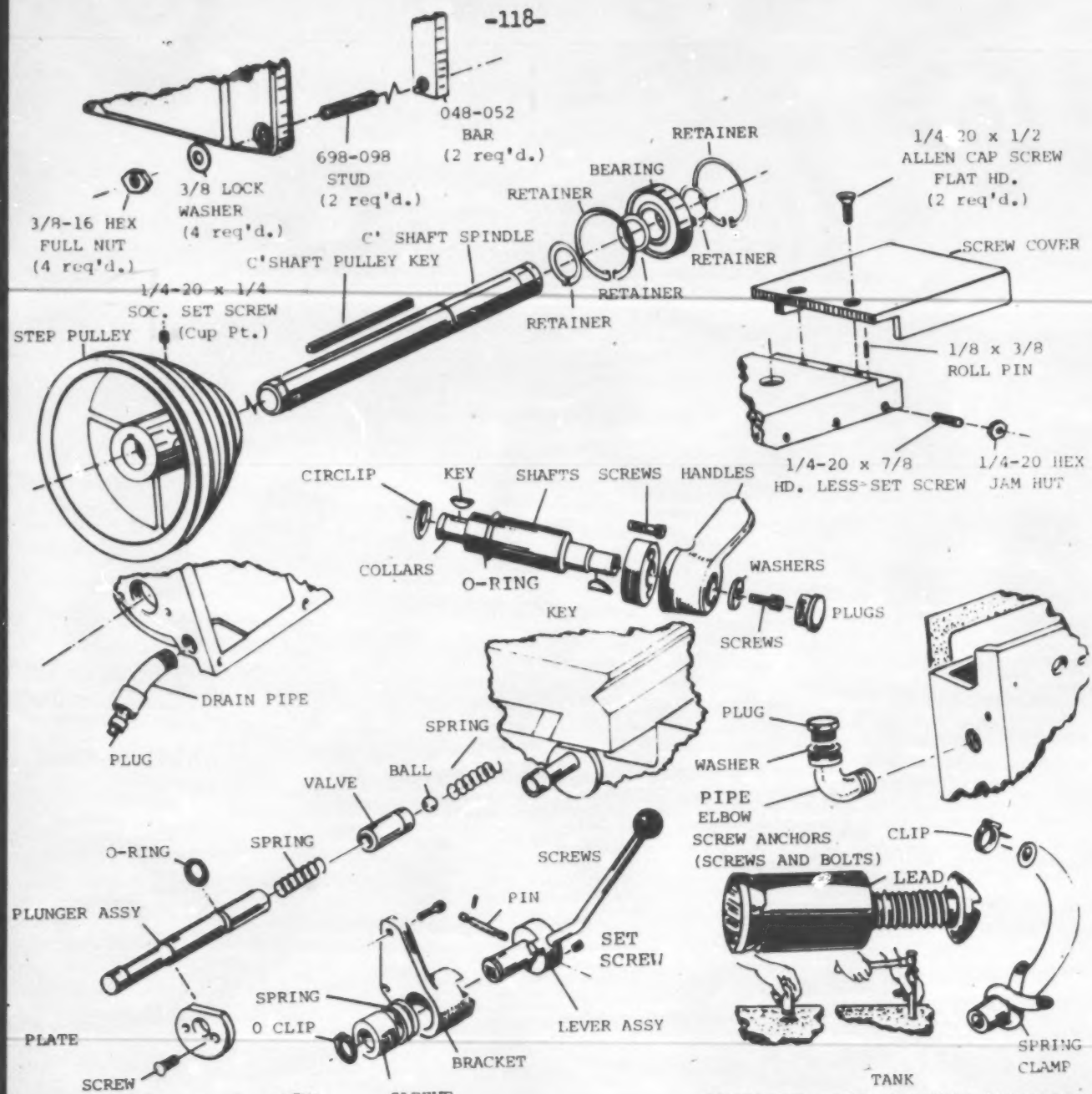
Electric soldering iron

LABORATORY

The student should solder brass, steel and cooper using a soldering copper, propane torch, electric soldering copper, or an electric soldering gun. He/she should use both solid solder and cored solder and acid and paste flux.

VI-8 FASTENERS Fasteners shown in Chapter III are used in many assemblies.



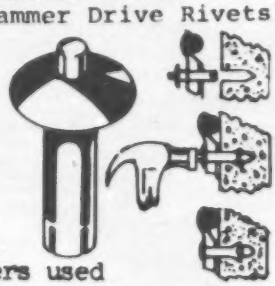


WALLGRIPS
SCREW ANCHORS

CONCRETE- AND MASONRY ANCHORS

FOR BLIND HOLDS
IN WOOD OR PLASTIC

MASONRY ANCHOR
(Hammer Drive Rivets)

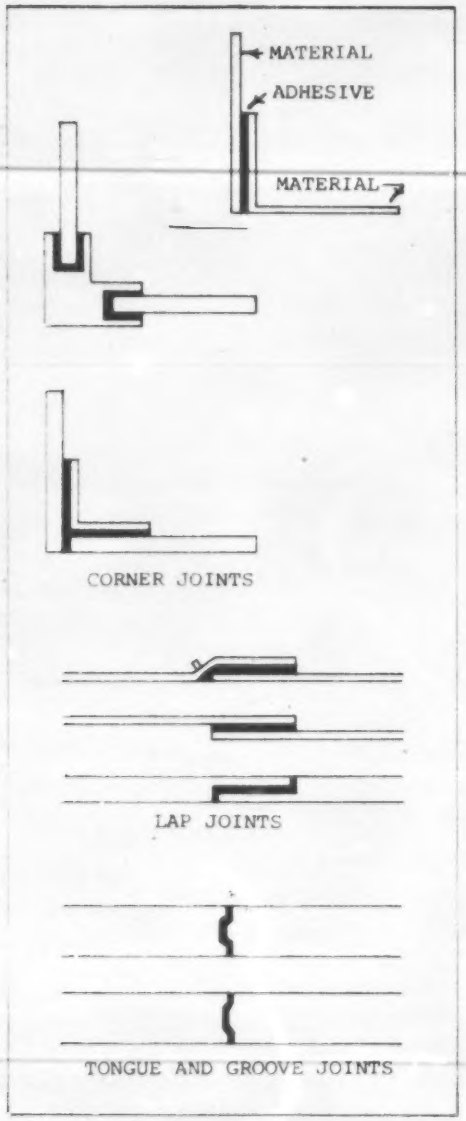


LABORATORY

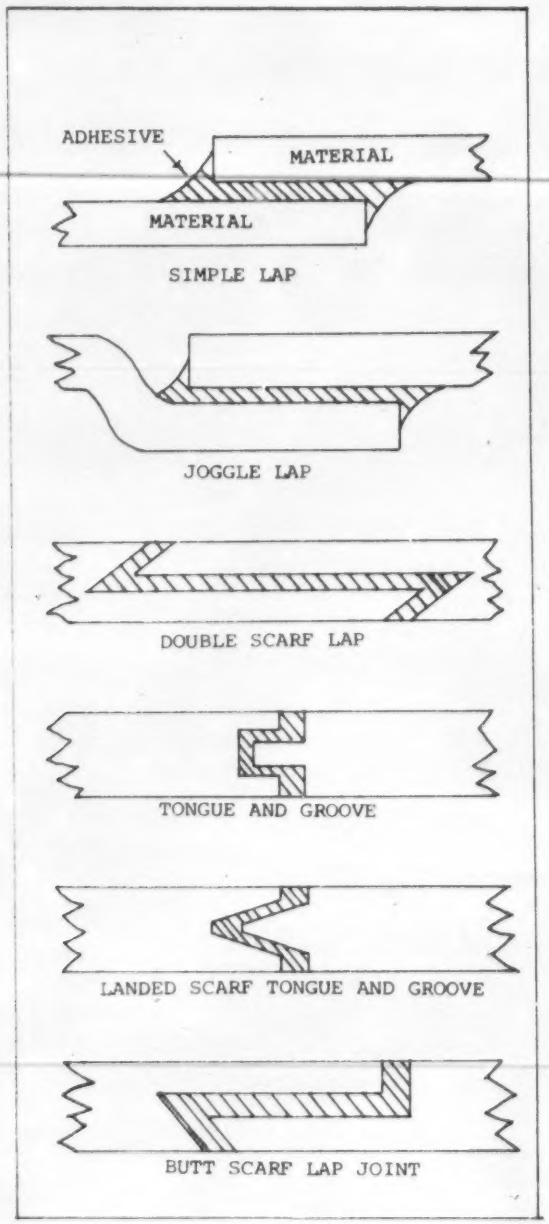
A student lab project should include a study of fasteners used in different commercial products.

VI-9. ADHESIVE BONDING & CEMENTING

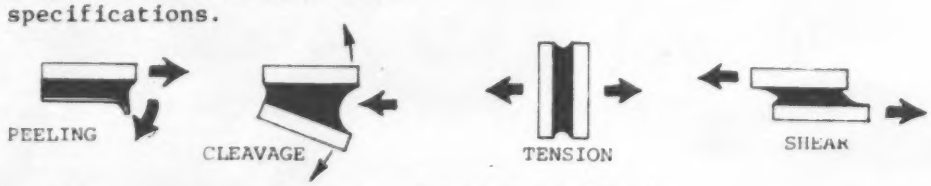
The process of connecting two pieces by a mechanical bonding adhesive or by melting the pieces together with a solvent cement.



Joints Suitable for Adhesive Bonding



Manufacturers literature specifies adhesive selection, information, and specifications.



Forces to Which Adhesive Bonds are Subjected

LABORATORY

The student should make and assemble different types of bonded and cemented joints using a variety of adhesives and materials.

SECTION ITEMS

1. Using techical tables determine the curing time for pliobond cement. (24 hrs)

2. A fire safe contact cement is needed. Determine a possible supplier. _____(Wilhold Glugs Inc.)

3. An epoxy is needed which will set within 20 minutes. Determine a supplier. _____(L.A. Kling Enterprises)

TABLE I

The Metric System of Measurement

The metric system in use today is a modern version of the metric system established by international agreement. It provides a logical and interconnected framework for all measurements in science, industry, and commerce. Officially abbreviated SI, the system is built upon a foundation of seven base units, which appear on this chart along with their definitions. All other SI units are derived from these units. Multiples and submultiples are expressed in a decimal system. Use of metric weights and measures was legalized in the United States in 1866, and since 1893 the yard and pound have been defined in terms of the meter and the kilogram. The base units for time, electric current, amount of substance, and luminous intensity are the same in both the customary English and metric systems.

THE INTERNATIONAL SYSTEM OF UNITS-SI

COMMON CONVERSIONS Accurate to Six Significant Figures				
Symbol	When you Know	Multiply by	To Find	Symbol
in	inches	[a] 25.4	[b] millimeters	mm
ft	feet	0.3048	meters	m
yd	yards	0.9144	meters	m
mi	miles	1.609 34	kilometers	km
yd^2	square yards	0.836 127	square meters	m^2
	acres	0.404 686	[c] hectares	ha
yd^3	cubic yards	0.764 555	cubic meters	m^3
qt	quarts (lq)	0.946 353	[d] liters	l
oz	ounces (avdp)	28.349 5	grams	g
lb	pounds (avdp)	0.453 592	kilograms	kg
F	Fahrenheit temperature	[a] 5/9 after subtracting 32)	Celsius temperature	^oC
mm	millimeters	0.039 370 1	inches	in
m	meters	3.280 84	feet	ft
m	meters	1.093 61	yards	yd
km	kilometers	0.621 371	miles	mi
m^2	square meters	1.195 99	square yards	yd^2
ha	[c] hectares	2.471 05	acres	
m^3	[d] cubic meters	1.307 95	cubic yards	yd^3
l	[d] liters	1.056 69	quarts (lq)	qt
g	grams	0.035 274 0	ounces (avdp)	oz
kg	kilograms	2.204 62	pounds (avdp)	lb*
^oC	Celsius	[a] 9/5 (then add 32)	Fahrenheit temperature	^oF

[a] exact

[b] for example 1 in = 25.4 mm, so 3 inches would be (3 in)(25.4 $\frac{mm}{in}$)=76.2mm

[c] hectare is a common name for 10,000 square meters

[d] liter is a common name for fluid volume of 0.001 cubic meter

Note: Most symbols are written with lower case letters; exceptions are units named after persons for which the symbols are capitalized. Periods are not used with any symbols.

* 1 LBM = pounds (avdp)

TABLE II

Fluxes for Soft Soldering

Metal to be Soldered	Flux	Chemical Name of Flux
Brass	Cut acid	Zinc chloride
Copper	Rosin	Colophony
	Sal ammoniac[1]	Ammonium chloride
Zinc	Cut acid	Zinc chloride
Galvanized iron (zinc coated)	Raw acid (muriatic acid)	Hydrochloric acid
Iron	Cut acid	Zinc chloride
Steel	Sal ammoniac	Ammonium chloride
Tin	Rosin	Colophony
Tin plate	Cut acid	Zinc chloride
Pewter	Rosin	Colophony
	Tallow	
Nickel	Chloride	Zinc chloride
Silver		
Aluminum	Special fluxes by different manufacturers	

[1]Sal ammoniac - a white solid substance that looks like rock salt or rock candy; it is used as a soldering flux. Sal ammoniac changes state directly from a solid to a gas (sublimes).

TABLE III

Sizes of Taps & Drills

Size of Tap		Outside Diameter (Inches)	Root Diameter (Inches)	Size of Tap Drill (For 75% Thread Depth)			Clearance Drill (Inches)		Clearance (Inches)
UNC NC (USS)	UNF NF (SAE)			Number and Letter Drills	Fractional Drills	Decimal Equivalent	Size	Decimal Equivalent	
	#0-80	0.0600	0.0438	...	3/64	0.0469	#51	0.0670	0.0070
#1-64	...	0.0730	0.0527	53	...	0.0595	#47	0.0785	0.0055
	#1-72	0.0730	0.0550	53	...	0.0595	#47	0.0785	0.0055
#2-56	...	0.0860	0.0628	50	...	0.0700	#42	0.0935	0.0075
	#2-64	0.0860	0.0657	50	...	0.0700	#42	0.0935	0.0075
#3-48	...	0.0990	0.0719	47	...	0.0785	#36	0.1065	0.0075
	#3-56	0.0990	0.0758	45	...	0.0820	#36	0.1065	0.0075
#4-40	...	0.1120	0.0795	43	...	0.0890	#31	0.1200	0.0080
	#4-48	0.1120	0.0849	42	...	0.0935	#31	0.1200	0.0080
#5-40	...	0.1250	0.0925	38	...	0.1015	#29	0.1360	0.0110
	#5-44	0.1250	0.0955	37	...	0.1040	#29	0.1360	0.0110
#6-32	...	0.1380	0.0974	36	...	0.1065	#25	0.1495	0.0115
	#6-40	0.1380	0.1055	33	...	0.1130	#25	0.1495	0.0115
#8-32	...	0.1640	0.1234	29	...	0.1360	#16	0.1770	0.0130
	#8-36	0.1640	0.1279	29	...	0.1360	#16	0.1770	0.0130
#10-24	...	0.1900	0.1359	25	...	0.1495	13/64	0.2031	0.0131
	#10-32	0.1900	0.1494	21	...	0.1590	13/64	0.2031	0.0131
#12-24	...	0.2160	0.1619	16	...	0.1770	7/32	0.2187	0.0027
	#12-28	0.2160	0.1696	14	...	0.1820	7/32	0.2187	0.0027
1/4"-20	...	0.2500	0.1850	7	...	0.2010	17/64	0.2656	0.0156
	1/4"-28	0.2500	0.2036	3	...	0.2130	17/64	0.2656	0.0156
5/16"-18	...	0.3125	0.2403	F	...	0.2570	21/64	0.3281	0.0156
	5/16"-24	0.3125	0.2584	I	...	0.2720	21/64	0.3281	0.0156
3/8"-16	...	0.3750	0.2938	...	5/16	0.3125	25/64	0.3906	0.0156
	3/8"-24	0.3750	0.3209	Q	...	0.3320	25/64	0.3906	0.0156
7/16"-14	...	0.4375	0.3447	U	...	0.3680	29/64	0.4531	0.0156
	7/16"-20	0.4375	0.3725	...	25/64	0.3906	29/64	0.4531	0.0156
1/2"-13	...	0.5000	0.4001	...	27/64	0.4219	33/64	0.5156	0.0156
	1/2"-20	0.5000	0.4350	...	29/64	0.4531	33/64	0.5156	0.0156
9/16"-12	...	0.5625	0.4542	...	31/64	0.4844	37/64	0.5781	0.0156
	9/16"-18	0.5625	0.4903	...	33/64	0.5156	37/64	0.5781	0.0156
5/8"-11	...	0.6250	0.5069	...	17/32	0.5312	41/64	0.6406	0.0156
	5/8"-18	0.6250	0.5528	...	37/64	0.5781	41/64	0.6406	0.0156
3/4"-10	...	0.7500	0.6201	...	21/32	0.6562	49/64	0.7656	0.0156
	3/4"-16	0.7500	0.6688	...	11/16	0.6875	49/64	0.7656	0.0156
7/8"- 9	...	0.8750	0.7307	...	49/64	0.7656	57/64	0.8906	0.0156
	7/8"-14	0.8750	0.7822	...	13/16	0.8125	57/64	0.8906	0.0156
1"- 8	...	1.0000	0.8376	...	7/8	0.8750	1 1/64	1.0156	0.0156
	1"-14	1.0000	0.9072	...	15/16	0.9375	1 1/64	1.0156	0.0156

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